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STUDIES OF SEWAGE PURIFICATION

VI. BIOCHEMICAL OXIDATION BY SLUDGES DEVELOPED BY PURE CULTURES OF BACTERIA ISOLATED FROM ACTIVATED SLUDGE

By C. T. BUTTERFIELD, *Principal Bacteriologist*, C. C. RUCHHOFT, *Principal Chemist*, and P. D. MCNAMEE, *Assistant Chemist, United States Public Health Service, Stream Pollution Investigations, Cincinnati, Ohio*

The research studies of the activated sludge process of sewage purification being carried on by the Stream Pollution Investigations laboratory of the United States Public Health Service at Cincinnati, Ohio, under the direction of Senior Sanitary Engineer J. K. Hoskins, include an investigation of the fundamental mechanism of the process. During recent years there has been intensive study of the activated sludge method of sewage treatment and many theories of the fundamental mechanism of the process have been proposed. In our studies of the total purification accomplished by activated sludge treatment, those portions of the purification which, after various periods of aeration, may be ascribed to (1) biochemical oxidation and (2) adsorption, which necessarily includes material utilized for the synthesis of new sludge solids, have been investigated. A study has also been made of those biological, chemical, and physical factors which facilitate or deter these basic phenomena of the process of total purification.

To avoid confusion due to involved results, each individual report insofar as possible will deal with only one such phase of the process and the data relative thereto. The present report will be confined to observations regarding the biochemical oxidation of organic matter occurring in sterilized natural sewage and in synthetic sewage when treated with active sludges developed by pure cultures of bacteria isolated from treatment plant activated sludge. In this report it will be shown that bacteria isolated from normal activated sludge can be made to reproduce similar sludge in pure culture and that this pure culture sludge exhibits oxidation characteristics similar to those of normal activated sludge.

Review of literature.—Edwards (1) has reviewed activated sludge theory and Theriault (2) has recently presented considerations on the rate and mechanism of sewage clarification. Streeter (3) summarized the work on rates of natural oxidation and showed that the

oxidation reaction is proportional to the biochemical oxygen demand and follows the equation expressed by Theriault (4),

$$X_t = L\,(1-10^{-Kt}) \qquad (1)$$

where

X_t = the B. O. D. oxidized in time t.
L = the initial total B. O. D.,
and K = a velocity constant of 0.1 at 20° C.

This low rate biochemical oxidation reaction has been assumed to hold for all sewage-sludge oxidation reactions. Higher rates of biochemical oxidation have not been demonstrated conclusively up to the present time, and observations indicating higher rates of oxidation usually have been ascribed to immediate or chemical demand.

The first study of rates of oxygen absorption by activated sludge was published by Grant, Hurwitz, and Mohlman (5). In this pioneer work the authors concluded that the rate of oxygen absorption for activated sludge was fairly uniform, that the rate was proportional to the organic (volatile) matter of the sludge, and that this rate for Chicago, North Side, activated sludge averaged about 7.0 milligrams of oxygen per gram of sludge per hour. They calculated the oxygen absorbed required to oxidize sewage by subtracting mean oxygen absorption values for activated sludge alone from the corresponding values for sludge plus sewage.

Theriault and McNamee (6) determined the rate of disappearance of oxygen in a sludge taken from an artificial stream channel and aerated in a closed system. It was found that the rate of oxidation for this sludge was much higher than could be accounted for by the biochemical oxidation rate in diluted sewage or natural waters. This high rate of oxidation was explained by them on the basis of two simultaneous unimolecular reactions, the first of these representing the normal biochemical oxygen demand and the second the so-called "immediate" oxygen demand. The expression representing the *reaction* is:

$$Y = L_1\,(1-10^{-K_1 t}) + L_2\,(1-10^{-K_2 t}) \qquad (2)$$

where

Y = the oxygen demand in time t in days,
L_1 and L_2 = constants for the total first stage demand, due respectively to biochemical oxidation and immediate demand,
K_1 = the velocity constant for the normal biochemical demand, equals 0.1,

and

K_2 = the velocity constant for the immediate demand.

The higher rate oxidation (L_2) in these experiments was practically complete in 20 hours and represented about 20 percent of the total first stage demand (L_1+L_2). The authors tentatively ascribed this high rate "immediate" demand to enzymatic action, and ruled out

the possibility that it might be due to a high rate biochemical oxidation reaction.

Kessler and Nichols (7), using a dilution method and short periods of observation (6 to 10 minutes), showed that the deoxygenation rate of sewage-activated sludge mixtures decreased rapidly during the first few hours. They observed that the maximum rate of deoxygenation of these mixtures was apparently dependent upon the sewage strength (B. O. D.). Furthermore, using Nordell's original empirical expressions, they found a fairly constant relation between the total oxygen used at the maximum rate by activated sludge-sewage mixtures and the 5-day B. O. D. of the sewage being treated by a given activated sludge. The factor for this relation varied from 6.0 to 13.0 for various activated sludges. This is an important observation, because it suggests that the deoxygenation reaction in sewage-activated sludge mixtures is a biochemical one in which the sludge organisms are the agents that oxidize sewage organic matter at rates very greatly increased over those which occur in sewage alone. The experiments of Wooldridge and Standfast (8), also reported by Topley (9), showed that, when sewage was added to activated sludge, there was an increase in the rate of oxygen absorption over that observed in activated sludge alone or in sewage alone. These experiments also indicate a more rapid biochemical oxidation of sewage organic matter by activated sludge than occurs in diluted sewage or in streams.

Goldthorpe (10) obtained rates of oxygen absorption by activated sludges from 0.021 to 0.173 milligrams of oxygen per gram of sludge per minute. In three experiments he determined the oxygen used by the sludge alone and immediately afterward the oxygen used by the sludge diluted with tank effluent. The data obtained were as follows:

Milligrams of O_2 absorbed per minute per gram of sludge

Experiment number	*4*	*5*	*6*
Sludge+tank effluent (1:2)	0.173	0.095	0.124
Sludge alone	.0259	.029	.023
Number of times rate was increased by addition of tank effluent	6.7	3.28	5.4

This illustrates the importance of the liquid substrate B. O. D. upon the rate of oxygen utilization of the sludge mixture. Goldthorpe's Huddersfield reaerated concentrated sludges apparently have very little dissolved food material in their liquid substrate. Consequently their rates of oxygen absorption are very low. When tank effluents, which still have considerable B. O. D. or dissolved organic food material present, are added to these sludges, the rate of oxidation increases tremendously, as is illustrated in these experiments.

Heukelekian (11) studied oxidation rates in activated sludge-sewage mixtures by determining the carbon dioxide produced. He confirmed Wooldridge and Standfast's observations that the oxidation rates in sewage-activated sludge mixtures were generally higher than occurred in the sewage and sludge separately. He also observed that in some cases a definite retardation of the oxidation rate took place when sludge and sewage were mixed. Activated sludge, however, showed a more rapid rate of oxidation than fresh solids even though the fresh solids contained a greater amount of oxidizable material. These experiments indicate again that when activated sludge with its established massive aerobic flora is aerated, high biochemical oxidation rates are obtained.

McNamee (12) determined the rates of oxidation in sludge alone and in mixtures of sludge plus sewage, using the same sludge in each case and carrying out the tests simultaneously. He assumed that the oxidation of the sludge at the same temperature and pH would be the same in each case and that the difference between the results obtained would represent the oxidation of the sewage by the activated sludge. From his studies with three sludges he concluded that the soluble and colloidal matter in sewage is oxidized much more rapidly than has been realized, and that a large part of the oxidation required for the stabilization of the oxidizable substances present in sewage occurs during the first few hours of contact with "good" activated sludge.

Butterfield (13) reviewed that portion of the literature of activated sludge which deals with the significance of the bacteria in this purification process and reports the isolation of a zooglea-forming bacterium from activated sludge. This zoogleal organism, in pure culture, in sterilized sewage under aeration produced a floc which simulated activated sludge. This pure culture floc was shown to bring about, during a 3-hour aeration interval, a 41 to 84 percent removal of the oxidizable material present in sewage. Such an extensive purification in such a short period suggests that this organism, or organisms of this type, are of very definite importance in this process. This purification was measured by determining the total amount of oxidizable material removed from the sewage without reference to the mode of its removal. It may have been adsorbed by the pure culture sludge, it may have been oxidized biochemically by the massed bacteria in the sludge, or both of these factors may have played a part in the purification process during the 3-hour aeration interval.

EXPERIMENTAL WORK—METHODS

Data will now be presented showing the portion of this total purification accomplished by pure culture sludges which can be attributed to biochemical oxidation.

1. *Isolation of bacterial cultures.*—In isolating cultures for this study, an effort was made to select organisms from good activated sludge which appeared to make up a marked and, in some cases, a major proportion of the bacterial content of the sludge. A number of cultures have been isolated from sludge produced in the station experimental plant and from activated sludges developed in regular plant installations in two other locations. The procedure followed in making the isolations was essentially the same as that previously used and described by one of us (Butterfield (13)). The fundamental characteristics of the bacteria thus isolated suggest that they all belong to the same general group of organisms as the zooglea-forming bacterium previously described. These cultures were isolated and propagated in synthetic media and in sterilized sewage. Ample precautions were taken in each instance to insure the purity of the cultures employed. Three different strains of zoogleal bacteria were used in these experiments. One of these strains was isolated from the station experimental plant, while the other two were obtained from two separate samples of activated sludge from the Lancaster, Pa., plant.

2. *Substrates.*—Sterile substrates were essential for the development of pure-culture sludges. Two kinds of substrate were employed: (*a*) Natural sewage sterilized by steam pressure in the autoclave, and (*b*) synthetic sewage, i. e., solutions simulating natural sewage.

(*a*) Natural sewage: Sterilization by heat was adopted as the most satisfactory procedure for obtaining a sterile natural sewage. While it is recognized that this procedure changes to some extent the natural condition of the sewage, experiments have shown that it altered the sewage less than other methods of sterilization which were available and that the sewage sterilized thus was adequately suitable for the development of good activated sludge. To determine definitely the difference which might exist between sludges developed on sterilized sewage and sludges developed on portions of the same sewage left in its natural state, the following-described experiments were carried out:

A mixture of good activated sludge and sewage was collected and 8 liters were placed in each of 2 aeration vessels, labelled A and B. Aeration was continuous at the same rate in both vessels except for 30-minute periods each day when the sludges were allowed to settle. At this period each day 5 liters of supernatant were withdrawn from each and in A this was replaced with 5 liters of fresh natural sewage while in B it was replaced with an equal amount of the same sewage which had been sterilized by heat and cooled prior to use. After this procedure had been carried on over a period of 48 days, through 41 such changes, the residual sludges were tested. These tests included suspended solids determinations, ash analyses and determinations of purification efficiency when the sludges were dosed with aliquot portions of the same natural sewage unsterilized. The purification efficiency was measured (by tests fully described later in this text), in each case after ½, 2, 4, and 24 hours' aeration by the total oxidizable material removed from the supernatant, by the amount of pollutional material oxidized biochemically, and by the amount of oxidizable material adsorbed by

the sludges. The agreement between the results obtained from the two sludges was excellent, in no instance differing by more than 5 percent.

This finding was considered a very definite indication that sewage sterilized by heat could be safely employed in our studies.

(*b*) *Synthetic sewage.*—The development of sludge in sewage under aeration has been universally observed. The source of this sludge has been to a great extent a matter of conjecture and theory. In sludge developed from normal sewage the source might readily be the solids present, altered somewhat by aeration and physical changes, or this sludge development might be aided by biological growth or by precipitation of dissolved and colloidal constituents of the sewage. To be able to observe accurately the influence of pure cultures of bacteria in sludge production and in the oxidation of pollutional material by such sludge, it was pertinent, in at least a few tests, that these bacteria be permitted to develop in solutions containing essentially the same dissolved constituents as sewage but which were entirely free from detritus and suspended substances of any description. Under such conditions, in a solution perfectly clear and free from all undissolved particles, sludge production should be readily observed and, if produced, could be definitely attributed to the activity of the bacteria present in pure culture. A stock solution of such characteristics was prepared and used in certain of our tests. The composition of this synthetic sewage was as follows:

Peptone, Difco, Bacto grade	gram	0.3
Meat extract, Liebigs	do	0.2
Urea, C. P. grade	do	0.05
Disodium hydrogen phosphate, C. P	do	0.05
Sodium chloride, C. P	do	0.015
Potassium chloride, C. P	do	0.007
Calcium chloride, C. P	do	0.007
Magnesium sulphate, C. P	do	0.005
Water, distilled	milliliters	1,000

After sterilization this substrate was perfectly clear and had a hydrogen ion concentration of pH 7.3 to 7.4. The mineral salt content was approximately the same as that of sewage. The urea content was calculated to be about the same as that of domestic sewage, basing the calculation on Hawk and Bergeim's (14) data for the average amount of urea in urine excreted per capita per day and assuming the average daily pumpage of water per capita as the normal dilution. Sufficient amounts of peptone and meat extract were added to the solution to make its biochemical oxygen demand approximately the same as that of a strong domestic sewage. The pure cultures of bacteria being studied in these tests developed a well organized floc under aeration in this synthetic sewage in from 24 to 48 hours after inoculation. This floc would continue to accumulate under the conditions of the tests until a well-developed sludge was present. Micro-

scopic examination of these flocs revealed that they were composed principally, if not entirely, of closely packed masses of bacterial cells surrounded by a gelatinous matrix.

3. *Production of pure culture sludge.*—In developing the pure culture sludges for use in this series of experiments the procedure was the same with both sterilized natural sewage and synthetic sewage. Eight liters of sewage were placed in a 10-liter serum bottle which was equipped with a diffuser ball and inlet and outlet tubes for continuous aeration under aseptic conditions. The entire set-up was placed in the autoclave and sterilized under steam pressure. After this sewage had cooled and stood for at least 24 hours, tests for sterility and hydrogen-ion concentration were made. If the reaction was not between pH 6.8 and 7.4, it was adjusted with sterilized dilute phosphoric acid or sodium hydroxide. The sterile substrate was then inoculated with a pure culture, usually 1 ml of broth culture to the 8 liters, and aeration was started at once. As soon as a well-formed floc had developed, settling for 30 minutes was allowed and 5 liters of supernatant were siphoned off through a sterile siphon. The 5 liters withdrawn were replaced with the same amount of sterile sewage and aeration was resumed. This procedure of withdrawing the supernatant and adding fresh food was repeated once daily, except Sunday, until sufficient sludge had developed to provide material for the desired tests. This usually required from 10 days to 3 weeks. The pH of the supernatant was determined at each change, and the reaction of the sterile liquid added was so adjusted that the pH of the resultant mixture would be in the desired range of 6.8 to 7.4. The adjustment invariably required the addition of sterile dilute phosphoric acid, never alkaline solutions, as these cultures always produced an alkaline reaction.[1] Suspended solids determinations of the mixture were made from time to time to determine when sufficient sludge had developed for the tests.

4. *Preparation for experiment.*—After thoroughly mixing the 8 liters of pure-culture sludge developed as previously described, 1-liter portions were poured into each of two 1-liter cylinders. The sludge in the two cylinders and that remaining in the 10-liter bottle was allowed to settle for 30 minutes and the amount of supernatant that could be removed without disturbing the settled sludge was determined. This amount varied from 625 ml to 900 ml for the liter cylinders. For illustrative purposes, suppose that 800 ml could be removed; then this amount was siphoned from each of the liter cylinders and a proportionate amount, in this case 4,800 ml, was siphoned from the 6 liters remaining in the 10-liter bottle. Eight

[1] These cultures did not oxidize ammonia compounds to nitrites or nitrites to nitrates. It is reasonable to assume that if a balanced inoculation had been made, including the nitrifying bacteria, the byproducts of the combined oxidations would have tended to keep the reaction neutral. Additional experiments with the nitrifying bacteria in pure culture and in combination with the carbonaceous oxidizers are contemplated.

hundred and twenty-five ml of formula C (15) dilution water were added to one cylinder, 825 ml of the test feed (sterilized natural sewage or synthetic sewage) were added to the other, and 4,950 ml of the same feed were added to the 10-liter bottle. Immediately after mixing, 25 ml portions were removed from each cylinder and the large bottle for determination of the pH and suspended solids. The sludge mixtures in the cylinders were transferred to two special high-form 4-liter aeration bottles which were clamped to the closed system aeration apparatus.

Aeration was started simultaneously in the 10-liter bottle and samples of supernatant were removed for the determination of total purification at the same time intervals that the closed system aeration bottles were examined.

The analyses made for each experiment include:

(1) Dilution method B. O. D. determinations for periods of 2, 5, 7, 10, and, in the last four experiments, 15 and 20 days, were made on

(*A*) The old supernatant removed.

(*B*) The initial feed added.

(2) pH, suspended solids, and ash determinations on initial and after 24 hours' aeration samples of

(*C*) Sludge—dilution water mixtures in closed system aeration bottle (i. e., control for aeration method B. O. D.);

(*D*) Sludge—feed mixtures in closed system aeration bottle (i. e., sample for aeration method B. O. D.);

(E) Sludge—feed mixtures in 10-liter open-system aeration bottle (i. e., sample for total purification).

(3) The determination of the gaseous oxygen initially and after various periods, usually ½, 1½, 3, 5, 10, and 24 hours on (*C*) and (*D*).

(4) Dilution method B. O. D. for the same incubation periods as in (1) and after the same aeration periods as in (3) on the supernatant from (*E*).

As in this study we are dealing with pure-culture sludge fed with sterile sewage (natural or synthetic), all dilutions made up for B. O. D. determinations by the dilution method were seeded with stale settled sewage to insure a common inoculation and uniform results. The results obtained under (2) (*E*) and (4) dealing with the total purification accomplished are not presented or discussed in this paper, which is confined to biochemical oxidation alone.

5. *Apparatus and technique for aeration method B. O. D. determinations.*—The apparatus and technique developed by Theriault and Butterfield (16) for determining the B. O. D. by aeration in a closed system is ideally suited for our study. Figure 5, which shows an assembly of this apparatus, is presented in the appendix. The cam shaft D, driven by an electric motor, imparts a reciprocating motion to the plunger in the mercury U-tube. This alternately increases

and decreases the air pressure on the aeration line connecting one limb of the U-tube with the aeration bottle. On the upstroke the lower valve E acts as a seal, and air is drawn in through valve V. On the down stroke the ball valve V closes and bubbles of air are forced into the liquid. With a cam shaft speed of about 150 to 175 r. p. m. very satisfactory aeration can be maintained in the apparatus. Four duplicates of this apparatus were set up in a 20° C. constant-temperature room, and all the experiments in this paper have been carried out at that temperature. Details of the technique for the collection and analysis of the gas samples from this apparatus are given in the appendix.

EXPERIMENTAL DATA

The oxygen required for the oxidation of the control aeration mixtures in seven different experiments for various periods is shown in table 1. Table 2 shows the corresponding oxygen requirements for the feed aeration mixtures in the same experiments. The control and feed mixtures in each experiment were aerated simultaneously and examinations were made at the same time; the data are presented in separate tables simply for convenience. These tables contain in addition, corollary information regarding the cultures employed, the amount of pure culture sludge produced at the time of the test, the quantity of supernatant withdrawn and of fresh feed or dilution water added, the nature of the substrate feed added, and the 5-day biochemical oxygen demand, as determined by the excess oxygen dilution method, of the old supernatant and of the substrate feed added.

TABLE 1.—*Oxidation in Control Aeration Mixtures. Oxygen used when pure culture sludge suspension in synthetic or sterile sewage substrate is aerated but not fed*

x = Pure culture sludge. y = 1-day old supernatant substrate. d = Formula C. dilution water.

Exp. no.	Culture	P. P. M. susp. solids = x	P. P. M. 5-day B. O. D. of y	Composition of aeration mix. (liters)	Mg O_2 used per liter in indicated time in hours					
					½	1½	3	5	10	24
1	Z-4	1,420	17.6	$x+.375y+.625d$	7.6	8.9	13.2	17.8	-------	[3] 39.1
2	Z-4	1,632	16.2	$x+.375y+.625d$	6.1	6.9	11.3	18.7	-------	[3] 52.1
3b	Z-1	773	13.8	$x+.09y+.91d$	7.7	[1] 10.1	-------	[3] 15.9	-------	23.2
3a	Z-1	843	13.8	$x+1.0y$	11.3	[1] 15.8	-------	[3] 20.7	-------	35.8
4	Z-9	2,644	14.5	$x+0.1y+.9d$	5.3	9.9	13.5	32.2	35.9	48.1
5	Z-9	1,560	15.0	$x+0.1y+.9d$	12.0	12.8	14.8	18.5	25.2	38.6
6	Z-9	2,428	10.6	$x+0.1y+.9d$	8.0	11.7	17.4	19.6	37.0	60.8
7	Z-9	1,632	11.4	$x+0.1y+.9d$	9.2	5.1	17.1	15.2	22.9	34.4

[1] 2 hours. [3] 4 hours. [3] 22 hours.

TABLE 2.—*Oxidation in Feed Aeration Mixtures. Oxygen used when pure culture sludge suspension in synthetic or sterile sewage substrate is fed immediately before experiment and aerated*

x=Pure culture sludge. y=1-day old supernatant substrate. z=Substrate feed added.

Exp. no.	Culture	P. P. M. susp. solids=x	P. P. M. 5-day B. O. D. of z	Substrate feed z	Composition of aeration mixture (liters)	Mg O_2 used per liter in indicated time in hours					
						½	1½	3	5	10	24
1	Z–4	1,420	287	Sterile sewage	$x+.375y+.625z$	32.4	56.4	77.0	93.1	------	[3]151.0
2	Z–4	1,632	345	Synthetic sewage	$x+.375y+.625z$	37.1	86.2	118.2	139.7	------	[3]210.4
3	Z–1	877	220	Sterile sewage	$x+.09y+.91z$	28.4	[4]64.5	------	[3]91.4	------	182.4
4	Z–9	2,868	142	Sterile sewage	$x+0.1y+0.9z$	26.6	50.6	70.2	84.2	111.7	156.0
5	Z–9	1,728	170	Synthetic sewage	$x+0.1y+0.9z$	34.7	69.6	92.6	113.0	131.0	153.9
6	Z–9	2,544	170	Synthetic sewage	$x+0.1y+0.9z$	20.3	50.0	80.4	103.4	136.5	216.6
7	Z–9	1,632	142	Sterile sewage	$x+0.1y+0.9z$	29.6	46.0	63.4	79.6	97.7	138.3

[1] 2 hours. [3] 4 hours. [3] 22 hours.

DISCUSSION AND INTERPRETATION OF RESULTS

In these experiments the pure-culture sludge has been considered as of negligible volume and as merely suspended in the substrate liquor. It is appropriate to consider the sludge as entirely separate from the substrate liquor, because the pure-culture suspended sludge is largely organized living agent. The substrate liquor in these experiments includes old supernatant containing the pure culture suspended solids, the fresh feed liquor, and, in the controls, dilution water. For convenience in discussing these results,

let

x=the pure culture suspended solids in one liter of mixed supernatant liquor,
y=one liter of old supernatant substrate,
z=one liter of fresh feed liquor,
d=one liter of dilution water,
p=fraction of y remaining,
q=fraction of z or d used.

Then the experimental set-up for a control sludge aeration mixture and a fresh feed-sludge aeration mixture necessary for one experiment may be represented as follows:

Bottle A: Fed aeration mixture=$x+py+qz$.
Bottle B: Control aeration mixture=$x+py+qd$.

As $x+py$ are equal in each mixture and qd has no biochemical oxygen demand then for a given time interval the difference between the oxygen requirements of the fed aeration mixture and the control mixture, $A-B$, is produced by the increment of sterile sewage added, qz. While any increase in the oxygen requirement of the fed aeration mixture, A, can be attributed definitely to the addition of the feed, qz, it cannot be ascribed to the oxidation of the added feed alone without further consideration.

It is recognized that at any period of examination there are three sources from which the bacterial mass may draw material for oxida-

tion; (1) from organic material originally derived from the substrate but now held adsorbed in the floc; (2) from dead bacterial cells also held in the floc; and (3) from material dispersed in the substrate. In successive time intervals from this period of examination the material drawn from these respective sources will vary and the variation will increase as the time interval between observations is increased. Thus the amount drawn from (1) may affect the amount drawn for replacement from (3) and this will affect in turn the bacterial birth and death rate, or the amount of (2) available for oxidation at the next examination. Under the conditions of our experiments, however, for short time intervals the amount of organic matter drawn and oxidized from (1) and (2) is independent of the amount originally present in or drawn from (3) and depends upon the quantity and condition of the sludge x at the start.

The oxygen requirement of the component, $x+py$, of the mixture $x+py+qz$, (A), cannot be determined separately when it is in the mixture. Without such a determination three possibilities exist in regard to the oxygen requirements of the component, $x+py$, of the mixture A, in the presence of added feed, qz, as compared with its oxygen requirement in mixture B in the absence of qz; (1) That the oxygen requirement of $x+py$ is increased and its satisfaction is accelerated by the presence of qz in A; (2) That the oxygen requirement of $x+py$ is decreased and its satisfaction is retarded by the presence of qz in A; or (3) That the oxygen requirement of $x+py$ is the same in A as it is in B and is satisfied at the same rate in both mixtures.

In considering possibility (1) if the oxygen requirements of $x+py$ were higher in A than they were in B, then in accordance with known laws, it would follow that the quantity of x or $x+py$ would decrease. As a matter of fact in a long series of observations the quantity of x or $x+py$ has never decreased but has always increased. Hence there could be no increased oxidation of $x+py$.

With regard to possibility (2), such an effect if it actually occurred would tend to decrease the real differences between the oxygen requirements of A and B, or to decrease the indicated oxygen requirement of the added substrate, qz, which had been satisfied. Thus this assumption, if true, would act as a safety factor for any deductions which might be made regarding accelerated oxidation produced by the pure culture sludges.

Considered from another angle, in these tests with the exception of experiments 6 and 7 which will be discussed later, the pure culture sludges had been subjected daily to the same treatment which was given in the test. This is particularly true for experiments 4 and 5 where the added substrate, qz, a synthetic sewage, could be, and was, exactly reproduced from day to day. Accordingly it is reasonable

to presume that the residual $x+py$ at the end of any test period was substantially the same as the $x+py$ present at the start of such test.

Consequently, as possibility (1) cannot be true and (2) if true would tend to decrease the magnitude of the results and serve as a safety factor for any deductions made it appears logical and sound to assume in interpreting the results of these tests that the difference between the oxygen requirements of the fed aeration mixture and of the control aeration mixture, $A-B$, represents substantially for the given time intervals the biochemical oxygen demand of the added substrate, qz, as produced by the pure culture activated sludge under aeration.

Data, which have been obtained with natural activated sludge, to prove that $x+py$ is oxidized at the same rate in A as it is in B will be presented in a later paper on oxidation by natural activated sludge. Such data for pure culture sludges were not obtained as the large quantities of sludge necessary for such experiments are extremely difficult to produce and maintain under pure culture conditions.

This method [2] of determining the oxygen required for the oxidation of the added substrate by the sludge has been used throughout these experiments. In one experiment (No. 3) two different controls and a feed mixture were all aerated simultaneously. One control contained the sludge suspended in 0.09 liter of old supernatant liquor and 0.91 liter of dilution water. The second control contained the same quantity of sludge suspended in 1.0 liter of old supernatant liquor. Each control has been used separately with the feed-sludge aeration mixture. The results with one control have been designated as Experiment 3a and with the other as Experiment 3b. This designation for the experiment has been used throughout this paper. It will be shown that, using the method of calculation introduced here, the results for the oxidation of the total substrate in the feed-sludge aeration mixture check remarkably well when obtained with these two different control set-ups.

In table 3 the results showing the oxygen required to satisfy the B. O. D. of the added increment of substrate for each experiment are recorded. These results are obtained by deducting the values given in table 1 (oxygen required to oxidize the control aeration mixtures) from the corresponding values given in table 2 (oxygen required to oxidize the feed-aeration mixtures). It will be noticed that the values in table 3 for the oxidation of the added increment are considerably larger than the values in table 1 for the oxidation of the sludge suspension plus a portion of the old supernatant substrate. This great difference illustrates the tremendous importance of the B. O. D. of the substrate feed on the oxidation rates of sludge aeration

[2] This method is valid for determining the oxygen required to oxidize sewage only if the sludge control is a portion of the same sample used to treat the sewage, and if the absorption tests are carried out simultaneously as will be shown later.

mixtures. The significance of the effect of the substrate feed on oxidation rates is more readily observed by referring to figure 1, where the results for a typical experiment (No. 1) are graphically presented. These results also illustrate the marked efficiency of the pure culture sludge in the oxidation of sewage.

TABLE 3.—*Oxidation of Added Increment. Oxygen used to oxidize the increment of substrate added. (Mg O_2 used by feed culture minus mg O_2 used by the control)*

x=Pure culture sludge. *y*=1-day old supernatant substrate. *z*=Substrate feed.

Exp. no.	Feed mixture (liters) (1)	Control mixture (liters) (2)*	Added increment (1)−(2) (liters) (3)	5-day B. O. D. of added increment	Mg O_2 used in oxidizing added increment in indicated time in hours					
					½	1½	3	5	10	24
1	x+.375y+.625z	x+.375y	.625z	179.7	24.8	47.5	63.8	75.3	------	[3] 111.9
2	x+.375y+.625z	x+.375y	.625z	215.6	31.0	79.3	106.9	121.0	------	[3] 158.3
3a	x+.09y+.91z	x+1.0y	−.91y+.91z	169.5	17.1	[1] 48.7	------	[2] 70.7	------	146.7
3b	x+.09y+.91z	x+.09y	.91z	200.0	20.7	[1] 54.4	------	[2] 75.5	------	159.3
4	x+.1y+.9z	x+.1y	.9z	127.8	21.3	40.7	56.7	52.0	75.8	107.9
5	x+.1y+.9z	x+.1y	.9z	152.6	22.7	56.8	77.8	94.5	105.8	115.3
6	x+.1y+.9z	x+.1y	.9z	152.6	12.3	38.3	63.0	83.8	99.5	155.8
7	x+.1y+.9z	x+.1y	.9z	127.8	20.4	40.9	46.3	64.4	74.8	103.9

[1] 2 hours. [2] 4 hours. [3] 22 hours.

* The necessary quantities of dilution water that were added to make the controls up to one liter have been omitted from this column because they do not enter into the calculation.

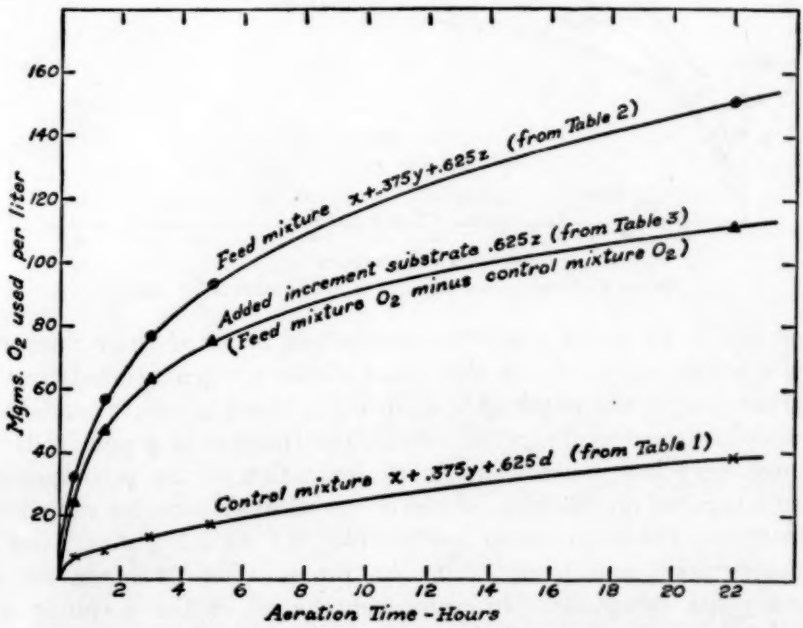

FIGURE 1.—Oxidation in pure-culture sludge-substrate aeration mixtures, Experiment 1.

From the data shown in table 3 the percentage of the 5-day B. O. D. of the added substrate oxidized by the pure culture sludge after various periods of aeration have been calculated and are pre-

sented in table 4. Typical oxidation curves expressed in these percentages during the 24-hour aeration period are shown in figure 2. An average of about 50 percent of the 5-day B. O. D. of the added substrate was oxidized during a 5-hour aeration interval. This rapid rate of oxidation is the more remarkable when one considers that it is carried on by bacteria in pure culture undoubtedly more restricted in their food habits than a grossly mixed culture would be. While definite information in regard to the food habits of these bacteria have not been obtained it is known that they do not oxidize nitrogen compounds to nitrites or nitrates.

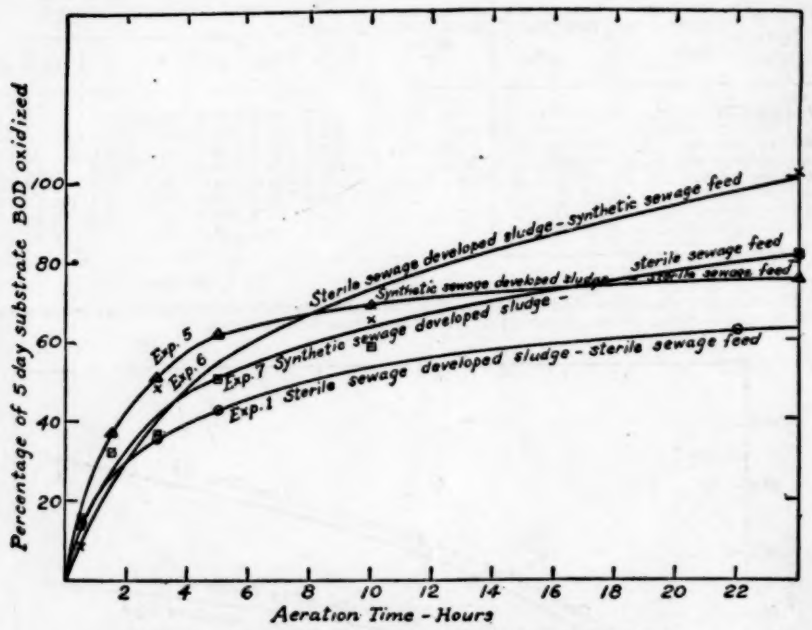

FIGURE 2.—Percentage of 5-day B. O. D. of total substrate oxidized.

As the B. O. D. of y was uniformly low in all of these mixtures it is a legitimate inference that most of the oxygen utilized by the mixture, $x+py$, was required to oxidize dispersate or solute condensed or absorbed on the sludge, x. While the fraction of y and its B. O D. was very low, corrections for the oxidation of the y component were estimated on the basis of the observed oxidations for the added substrate. These estimates varied from 0.1 to 1.1 p.p.m. after ½ hours aeration and from 1.0 to 4.5 p.p.m. after 24 hours for all experiments except 3*a*. In experiment 3*a* all of the y component was left in the control and the estimates in this case for the aeration periods given were 3.7 and 13.8 p.p.m. The application of these corrections provides for an estimation of the oxygen required to oxidize the sludge alone and of the oxygen required to oxidize the

mixed supernatant, *py+qz*. While these corrections may seem to be meticulous and so small as to be unnecessary they have been used.

TABLE 4.—*Percentage of the 5-day B. O. D. of the mixed supernatant substrate oxidized when aerated with pure culture sludge*

Exp. no.	Pure culture sludge developed on—	Substrate feed added for test	Percentage of 5-day B. O. D. oxidized in indicated time in hours					
			½	1½	3	5	10	24
1	Sterile sewage	Sterile sewage	13.8	26.6	35.7	42.1		[3] 62.5
2	do	Synthetic sewage	14.4	36.7	49.5	56.1		[3] 73.4
3a	do	Sterile sewage	9.2	[1] 26.1		[3] 37.8		79.0
3b	do	do	10.6	[1] 27.2		[3] 38.0		79.5
4	do	do	16.6	31.9	44.5	40.7	59.4	84.3
5	Synthetic sewage	Synthetic sewage	14.9	37.3	51.1	62.0	69.4	75.7
6	Sterile sewage	do	8.1	25.1	47.8	54.9	65.2	102.1
7	Synthetic sewage	Sterile sewage	16.0	32.0	36.2	50.5	58.7	81.4

[1] 2 hours. [3] 4 hours. [3] 22 hours.

TABLE 5.—*Milligrams of oxygen used to oxidize one liter of mixed supernatant substrate by pure culture sludge*

Exp. no.	B. O. D. of mixed supernatant substrate			MgO_2 used per liter in indicated time in hours					
	2-day	5-day	10-day	½	1½	3	5	10	24
1	109.3	185.9		25.7	49.3	66.2	78.1		[3] 116.0
2	174.3	221.7		31.9	81.5	109.9	124.4		[3] 162.8
3a	157.6	201.2	[4] 230.1	18.5	[1] 52.6	*64.5	[3] 76.5		158.8
3b	157.6	201.2	[4] 230.1	20.8	[1] 54.8	*65.4	[3] 76.0		160.4
4	90.0	129.3	135.3	21.5	41.3	57.6	52.6	76.8	109.0
5	113.0	154.1	205.7	22.9	57.5	78.7	95.5	107.0	116.6
6	112.9	153.7	205.4	12.4	38.6	63.5	84.4	100.2	156.9
7	89.8	128.9	135.3	20.6	41.3	46.7	65.1	75.6	104.9

[1] 2 hours. [3] 4 hours. [3] 22 hours. [4] 11 days.

*Estimated from 2- and 4-hour results.

Table 5 shows the oxygen used by pure culture sludge to oxidize 1 liter of mixed supernatant substrate. The values in table 5 differ from the corresponding values in table 3 by the small estimates for the oxidation of *py*. Figure 3 shows several typical substrate oxidation curves plotted from data in table 5. Here the marked efficiency of the pure culture sludges in the oxidation of pollutional material is again definitely apparent. Regardless of whether the sludge was developed on sterilized natural sewage or on synthetic sewage it was equally effective in oxidizing either synthetic sewage or sterilized natural sewage. The only difference noted was that the oxidation of the synthetic sewage appeared to be completed more rapidly. This, indeed, would be expected, for all of the oxidizable material in the synthetic sewage was in solution and readily available for bacterial oxidation.

It seems worth while to observe here that sludge was developed to the extent of 1,560 and 1,632 parts per million, respectively, in Experi-

ments 5 and 7, where synthetic sewage was employed. The development of this pure-culture activated sludge in a synthetic sewage containing all materials in true solution and free from suspended particles can be certainly attributed to the activity of the bacteria present in pure culture. Microscopic examinations of the individual flocs of this sludge showed that they were composed of closely packed masses of bacterial cells. The results obtained (tables 3, 4, and 5) show definitely that these sludges have the same oxidation efficiency as sludges developed in sterilized natural sewage.

To show the average performance of these pure-culture sludges in oxidizing the B. O. D. of the substrate, the mean number of milligrams

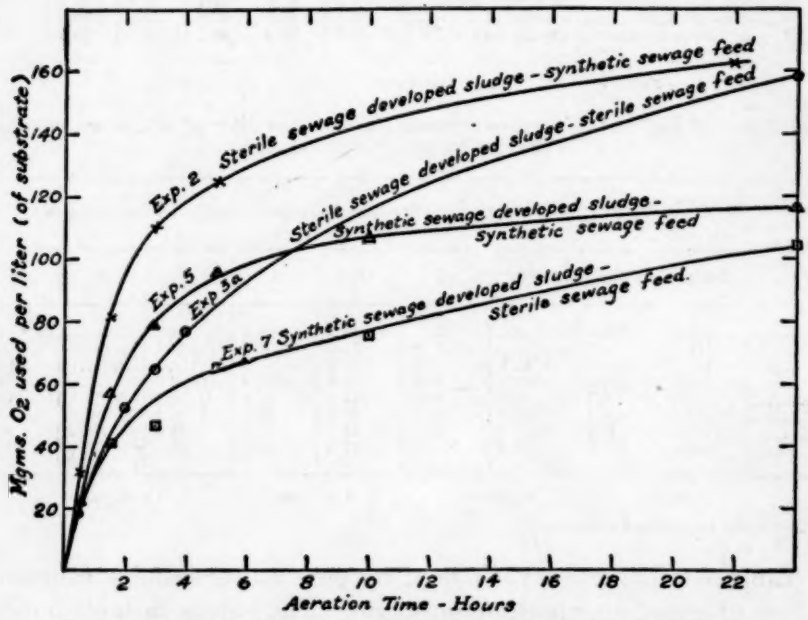

FIGURE 3.—Typical oxidation curves of supernatant substrate by pure-culture sludge.

of oxygen used for various units of aeration mixture have been calculated. The mean number of milligrams of oxygen, the standard deviation from the mean, and the percentage standard deviation for the results obtained at the ½-, 1½-, 3-, and 24-hour aeration periods are shown in table 6.

To determine the quantity of oxygen used to stabilize the pure culture sludge itself in these experiments, the milligrams of oxygen used to oxidize substrate as shown in table 5 are subtracted from the corresponding amounts of oxygen used in the entire feed aeration mixture as shown in table 2. The milligrams of oxygen used to oxidize sludge obtained in this way are shown in table 7.

TABLE 6.—*Mean milligrams oxygen used to oxdize substrate B. O. D. in all pure culture sludge experiments for various aeration mixture units*

Aeration time in hours	½			1½			3			24			Mean
	Mean mg O_2	S. D. ±	% S. D. ±	Mean mg O_2	S. D. ±	% S. D. ±	Mean mg O_2	S. D. ±	% S. D. ±	Mean mg O_2	S. D. ±	% S. D. ±	% S. D. ±
Per liter substrate (5-day B. O. D. 128.9 to 221.7)	21.8	5.26	24.1	48.7	13.7	28.2	70.3	17.8	25.3	135.7	24.4	18.0	23.9
Per 100 p. p. m. 5-day B. O. D. per liter substrate	12.9	3.05	23.6	28.8	6.4	22.2	41.1	7.8	19.0	79.8	10.5	13.1	19.5
Per gram suspended solids	15.3	6.50	42.3	33.6	13.5	40.2	48.9	21.1	43.2	97.7	55.2	56.6	45.6
Per gram volatile suspended solids	20.4	9.23	45.3	44.9	18.7	41.7	65.9	31.0	47.1	134.4	79.9	59.6	48.6
Per 100 p. p. m. 5-day substrate B. O. D. per gram suspended solids	8.6	2.98	34.7	18.9	5.1	27.0	27.2	7.7	28.3	55.1	23.5	42.7	33.1
Per 100 p. p. m. 5-day substrate B. O. D. per gram volatile suspended solids	11.0	3.62	32.9	25.0	6.5	26.0	36.5	11.3	31.0	74.1	34.3	46.3	34.1

S. D.=Standard deviation. % S. D.=Percentage standard deviation.

TABLE 7.—*Milligrams of oxygen used to oxidize the pure culture sludge suspension alone*

Exp. no.	P. P. M. sludge	Mg O_2 used to oxidize sludge in 1.0 liter of mixture in indicated time in hours						Mg O_2 used per gram of sludge in indicated time in hours						Mg O_2 used per gram of volatile solids in indicated time in hours					
		½	1½	3	5	10	24	½	1½	3	5	10	24	½	1½	3	5	10	24
1	1,420	6.7	7.1	10.8	15.0	----	35.0	4.7	5.0	7.6	10.6	----	[3]24.6	6.3	6.6	10.1	14.0	----	[3]32.6
2	1,632	5.2	4.7	8.3	15.3	----	[3]47.6	3.2	2.9	5.1	9.4	----	[3]29.2	4.2	3.8	6.7	12.4	----	[3]38.6
3a	843	9.9	[1]11.9	----	[2]14.9	----	23.6	11.7	[1]14.1	----	[2]17.6	----	28.0	16.6	[1]20.0	----	[2]25.0	----	39.6
3b	843	7.6	[1]9.7	----	[2]15.4	----	22.0	9.0	[1]11.5	----	[2]18.2	----	26.0	12.7	[1]16.3	----	[2]25.8	----	37.0
4	2,868	5.1	9.3	12.9	31.6	34.9	47.0	1.8	3.2	4.5	11.0	12.2	16.4	2.8	5.2	7.2	17.5	19.4	26.2
5	1,728	11.8	12.1	13.9	17.5	24.0	37.3	6.8	7.0	8.0	10.1	13.9	21.6	7.4	7.6	8.8	11.1	15.2	23.6
6	2,544	7.9	11.4	16.9	19.0	36.3	59.7	3.1	4.5	6.6	7.5	14.2	23.4	4.9	7.1	10.5	11.9	22.7	37.4
7	1,632	9.0	4.7	16.7	14.5	22.2	33.4	5.5	2.9	10.2	8.9	13.6	20.5	5.8	3.0	10.8	9.4	14.3	21.6

[1] 2 hours. [2] 4 hours. [3] 22 hours.

From the values in tables 7 and 2, the percentages that the oxygen used to oxidize sludge are of the total oxygen used in the feed aeration mixtures have been calculated. These percentages are shown in table 8 for all experiments. On the average, about 27.3 percent of the oxygen used in a freshly dosed pure-culture sludge during the first ½ hour of aeration is required to oxidize the sludge. This percentage drops to about 15 after 1½ hours of aeration and then apparently slowly rises, approaching the original figure after 24 hours.

TABLE 8.—*Percentage of the total oxygen used in fed pure culture sludge aeration mixtures that is required to oxidize the sludge alone*

Experiment no.	Percentage of total oxygen used to oxidize the sludge in indicated aeration time in hours					
	½	1½	3	5	10	24
1	20.6	12.6	14.0	15.0	----	[3] 23.2
2	14.0	5.5	7.0	11.0	----	[3] 22.6
3a	35.0	[1] 17.4	----	[2] 16.3	----	12.9
3b	26.7	[1] 15.0	----	[2] 16.9	----	12.0
4	19.1	18.4	17.9	37.7	31.2	30.2
5	34.0	17.4	19.2	15.4	18.3	24.2
6	38.8	22.8	21.0	18.4	26.6	27.5
7	30.0	10.2	20.0	18.2	22.8	24.1
Mean	27.3	14.9	16.5	18.6	24.7	22.1

[1] 2 hours. [2] 4 hours. [3] 22 hours.

The cause of this rather high percentage of oxygen (27) that is used to oxidize sludge during the first one-half hour is no doubt due to a degradation of the sludge during the preparation for the experiment while the sludge is settling and is not being aerated. A plausible explanation would seem to be that previous to the start of the experiment, the sludge has had no food material added for 24 hours, and during this time the easily available food material has become exhausted and a higher bacterial death rate has apparently set in, thus providing an increased proportion of food for the bacteria remaining, which is a contributory cause of the high oxygen consumption of the sludge during this period. During the next 2 to 4 hours, the sludge bacteria reach their maximum rates of oxidation and are apparently also reproducing at their maximum rate. The smallest portion of the total oxygen is used to oxidize the pure culture sludge during this period, and the percentage so used falls to about 15. After 4 or 5 hours the most easily available food supply is exhausted, and the rate of reproduction of the organisms falls while the death rate with the consequent increase in degradation products slowly rises. This results in a very slow increase in the percentage of oxygen that is being used to stabilize the sludge itself during the remainder of the 24-hour aeration period.

Table 9 shows the percentages of the total oxygen used in pure-culture sludge aeration mixtures that are required to oxidize the sludge for substrates of varying initial B. O. D. It will be noticed that the percentage of oxygen used to oxidize the sludge alone in an aeration mixture varies inversely with the B. O. D. of the substrate. When a pure culture aeration mixture having a B. O. D. of the substrate of 6 to 14 parts per million in 5 days was aerated about 86.9 to 83.4 percent of the oxygen used was required to oxidize the sludge during the first half hour. When the supernatant of such a mixture was withdrawn and a feed material was added until the 5-day B. O. D.

of the substrate was 172, the oxidation rate in the aeration mixture increased and the percentage of oxygen used to oxidize sludge fell to about 27.3 percent of the total used. This illustrates that the percentage of oxygen used by the pure culture sludge in a sludge-aeration mixture varies considerably depending apparently upon the condition of the sludge itself and the B. O. D. of the substrate.

TABLE 9.—*Percentage of total oxygen used in pure-culture sludge aeration mixtures that is required to oxidize sludge*

	No. of experiments	Mean substrate B. O. D., 5 days	Percentage of the total oxygen used to oxidize the sludge in indicated time in hours					
			½	1½	3	5	10	24
Feed-sludge mixtures	8	172.0	27.3	14.9	16.5	18.6	24.7	22.1
Sludge-old supernatant (x+1y)	1	13.8	83.4	75.3	------	74.4	------	66.0
Sludge-old supernatant (x+.375y+.625d)	2	6.35	86.9	74.0	81.1	83.2	------	90.4
Sludge-old supernatant (x+.1y+.9d)	4	1.28	97.8	94.5	95.3	96.0	96.6	96.8

The composite oxidation results for all experiments with pure-culture sludge have been calculated and are shown in table 10. These results are plotted in figure 4. The lower curve in this figure represents the average oxidation of the pure culture sludge alone. The intermediate curve shows the average oxidation of the substrate alone by the pure-culture sludge. The upper curve represents the total oxidation in the fed aeration mixtures, and each point on it includes the sum of corresponding points of the other two curves. The total oxidation curve for all substrate–sludge aeration mixtures can be separated into two components, one representing the oxidation of the sludge and the other the oxidation of the substrate. In this composite curve the oxidation of the sludge varies between 27 and 15 percent of the total oxidation. As the B. O. D. of the substrate falls, the substrate oxidation curve also falls and the oxidation of the sludge represents a larger proportion of the total oxidation, as has already been shown in table 9.

TABLE 10.—*Composite oxidation results for all experiments*

	Mg O_2 used per liter of fed-sludge aeration mixture in indicated time in hours				
	½	1½	3	5	24
Oxidation of pure-culture sludge	7.9	8.5	13.2	21.5	38.2
Oxidation of supernatant substrate	21.8	48.7	70.3	83.3	135.7
Total oxidation of aeration mixture	29.7	57.2	83.5	104.8	173.9

SUBSTRATE OXIDATION RATES EFFECTED BY PURE CULTURE SLUDGES

The expression, $y=L-[a(10^{-K_1 t})+b(10^{-K_2 t})]$, suggested by Theriault and McNamee (6), was graphically fitted to the substrate oxidation results shown in table 5. In this equation the constants a and b correspond to the L_1 and L_2 portions of the total demand. In fitting this expression to these results, the total first-stage demands (L values) were estimated from the 5-, 10-, and 20-day dilution method B. O. D. of the substrates, corrected for oxygen used to form nitrites and nitrates. The constants thus obtained are shown in table 11. The observed values (table 5) fitted the derived curves reasonably well and the constants indicate in all cases a very high rate biochemical oxidation by these pure-culture sludges. It will be noted that there is

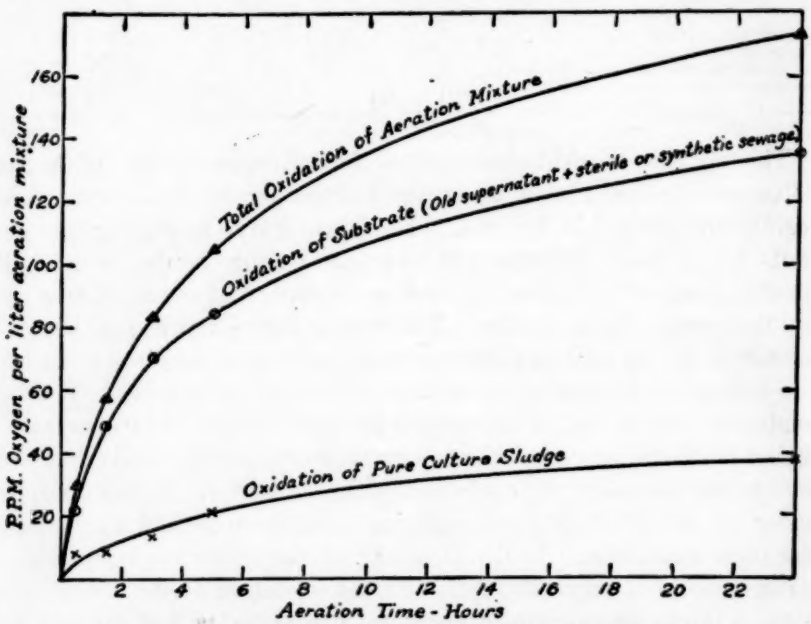

FIGURE 4.—Mean oxidation curve for all pure-culture sludge experiments.

considerable variation in the constants obtained from the several experiments, i. e., K_1 (the velocity constant for the rapid oxidation representing about 25 percent of the total carbonaceous demand) varies from 68 to 126 times the single velocity constant ordinarily accepted as representative of normal biochemical oxidation as observed in diluted samples or in streams. This variation probably was to be expected, as (1) these sludges were developed using three different strains of bacteria, each in pure culture; (2) five sludges were developed on sterilized natural sewage and two were developed on synthetic sewage; and (3) the feed was varied so that sludge developed on natural sewage was tested with synthetic sewage feed and sludge developed on synthetic sewage was tested with natural sewage feed.

TABLE 11.—*Constants for curves for substrate oxidation by pure culture sludge*

Constants to fit the expression $Y=L-[a(10^{-K_1 t})+b(10^{-K_2 t})]$

Exp. no.	L, estimated total carbonaceous demand	a	b	t expressed in hours		t expressed in days	
				K_1	K_2	K_1	K_2
1	[1] 274	65	209	.313	.0057	7.51	.136
2	[1] 326	109	217	.357	.0054	8.57	.129
3a	[2] 273	45	228	.377	.0122	9.05	.293
3b	[2] 273	46	227	.416	.0126	9.98	.302
4	[2] 176.5	41.5	135	.526	.0126	12.6	.302
5	[2] 217.8	74.8	143	.427	.0070	10.2	.168
6	[2] 216.0	51	161	.286	.0150	6.86	.360
7	[2] 179.7	51.7	128	.377	.0095	9.05	.227

[1] Estimated from 5-day B. O. D. values.
[2] Estimated from 5- and 10-day B. O. D. values.
[3] Estimated from 5-, 7-, 10-, 15-, 20-, and 35-day B. O. D. values corrected for NO_2 and NO_3 formed.

SUMMARY AND CONCLUSIONS

The literature dealing with the biochemical oxidation of sewage by activated sludge is reviewed briefly.

Various bacteria which make up a major portion of the bacterial flora of activated sludge have been isolated in pure culture. Employing these bacteria in pure culture, activated sludge has been produced in sterilized natural sewage and in sterile synthetic sewage. This production of activated sludge in synthetic sewage (which was entirely free from detritus and suspended substance) by pure cultures of bacteria is definite evidence that these bacteria, at least under the conditions of test, are responsible for the production of activated sludge. Using a procedure which has been developed for the determination of the rate of biochemical oxidation of activated sludge mixtures it was found that the addition of fresh nutrient substrate to these pure culture activated sludges under aeration very greatly increased the quantities of oxygen utilized. The increase observed when the oxygen requirements of fed mixtures and control mixtures are compared has been attributed to the oxidation of the added substrate.

The results show that about 50 percent of the 5-day B. O. D. of a sewage is oxidized by 5 hours' aeration with these pure-culture sludges and that about 80 percent of the 5-day B. O. D. is oxidized in 24 hours. Nitrogenous materials are not included in this oxidation as these bacteria are not capable of such action. With freshly dosed sludge the oxygen required for the oxidation of the sludge alone represented from 15 to 27 percent of the total.

The expression suggested by Theriault and McNamee was fitted to the data for the first stage, or carbonaceous oxidation of the substrate, obtained when sewage was aerated with these pure-culture sludges. The results indicate that, during the first 3 to 5 hours of

aeration, the velocity constant of the oxidation rate is 68 to 126 times greater than the established constant for normal biochemical oxidation in diluted samples or in streams. This rapid rate of oxidation "breaks" after 3 to 5 hours of aeration, but the velocity constant for the remainder of the 24-hour period is still considerably greater than the established constant.

It may be concluded from the results of these tests with sludges developed by bacteria in pure culture that reactions of the same general type are indicated in each test and that the velocity constants are all much greater than the constant for normal biochemical oxidation.

While it is desired to emphasize the primary importance of bacteria in the activated sludge process of sewage purification, it is not desired to create the impression that these bacteria, whose activities are reported, are the only ones which can promote rapid oxidation under such cond tions. No doubt there is a considerable group of organisms capable of such action. The primary prerequisite for this type of organism, in addition to oxidizing capacity, appears to be the ability to grow in a liquid medium in a massed floc or colony which binds itself together tenaciously enough to remain intact under the agitation of the aeration required to maintain aerobic conditions.

ACKNOWLEDGMENTS

It is desired to express our sincere appreciation to the members of the staff of the Stream Pollution Investigations Station of the United States Public Health Service for their assistance in preparing the drawings for the figures, in critically reviewing the paper, and especially to Assistant Bacteriologist Elsie Wattie for assistance in the analytical work and in the preparation of pure-culture sludges.

REFERENCES

(1) Edwards, G. P.: A review of activated sludge theory. Sewage Works Jour., 7: 17 (1935).
(2) Theriault, E. J.: Studies of sewage treatment. III. The clarification of sewage. A review. Sewage Works Jour., 7: 377 (1935). Also Pub. Health Rep.: 50, 1518 (1935). (Reprint No. 1715.)
(3) Streeter, H. W.: Measures of natural oxidation in polluted streams. I. The oxygen demand factor. Sewage Works Jour., 7: 251 (1935).
(4) Theriault, E. J.: Pub. Health Bull. No. 173, U. S. Public Health Service (1927).
(5) Grant, S., Hurwitz, E., and Mohlman, F. W.: The oxygen requirements of the activated sludge process. Sewage Works Jour. 2: 228–44 (1930).
(6) Theriault, E. J., and McNamee, P. D.: Experimental studies of natural purification in polluted waters. VI. Rate of disappearance of oxygen in sludge. Jour. Ind. Eng. Chem., 22: 1339 (1930). Also Pub. Health Rep., 46: 1301 (May 29, 1931). (Reprint No. 1480.)
(7) Kessler, L. H., and Nichols, M. S.: Oxygen utilization by activated sludge. Sewage Works Jour., 7: 819 (1935).
(8) Wooldridge, W. R., and Standfast, A. F. B.: Some experiments on the oxidation of sludge and sludge-sewage systems. Biochem. Jour., 30: 149 (1936).

(9) Report of the Water Pollution Research Board for the Year Ended 30th June, 1935. His Majesty's Stationery Office, London (1935).
(10) Goldthorpe, H. H.: Some experiments on the oxygen demand of an activated sludge. The Surveyor, 89: 351 (1936).
(11) Heukelekian, H.: Carbon dioxide production in mixtures of sewage and activated sludge. Sewage Works Jour., 8: 211 (1936).
(12) McNamee, P. D.: Oxidation of sewage by activated sludge. Sewage Works Jour., 8: 562 (1936). Also Pub. Health Rep., 51: 1034 (1936).
(13) Butterfield, C. T.: Studies of sewage purification. II. A zooglea-forming bacterium isolated from activated sludge. Pub. Health Rep., 50: 671 (1935). (Reprint No. 1686.)
(14) Hawk, P. B., and Bergeim, O.: Practical physiological chemistry, 10th edition, pp. 708–709 (1931). Blakiston's, Philadelphia, Pa.
(15) Theriault, E. J., McNamee, P. D., and Butterfield, C. T.: Experimental studies of natural purification in polluted waters. V. The selection of dilution waters for use in oxygen demand tests. Pub. Health Rep., 46: 1084 (1931). (Reprint No. 1475.)
(16) Theriault, E. J., and Butterfield, C. T.: Experimental studies of natural purification in polluted waters. I. Apparatus and technique for the study of biochemical and other oxidations in liquids. Pub. Health Rep., 44: 2252 (1929).

Appendix

TECHNIQUE FOR THE AERATION METHOD B. O. D. DETERMINATION

Before aerating the sludge mixtures, samples of gas from each closed aeration bottle are taken. Oxygen U-tube absorption vessels are required for each test. The stopcock A of the absorption vessel (see fig. 5) is turned to connect with the 2-ml cup; and with the stopper removed, distilled water of known oxygen content is siphoned into the right-hand limb of the U-tube. The delivery tube of the siphon is kept near the bottom of the U-tube, and water is added to fill the capillary bore leading to the 2-ml cup. The stopcock is then turned to communicate with the capillary tube alongside the cup.

The procedure used to obtain a sample of gas consists of the following steps: (1) Connect the water-jacketed gas burette with the aeration bottle; (2) the U-tube absorption vessel, filled with distilled water of known oxygen content, is connected to the gas burette; (3) the air in the capillary tube connecting the U-tube and gas burette is replaced by water drawn from the U-tube by lowering the mercury level of the burette; (4) the air and excess water are expelled from the apparatus, after turning the stopcock B 180°, by raising the mercury level of the burette; (5) the mercury level is allowed to rise above stopcock C and held in this position by closing the stopcock at the base of the burette; (6) the stopcock C is now turned 45° and the mercury allowed to flow back into the reservoir by opening the stopcock at the base of the burette; (7) the mercury level is now adjusted so that it is at the 10.000-ml graduation on the stem of the burette (the stopcock at the base of the burette is used to control this manipulation); (8) the 10-ml sample of gas is transferred to the U-tube absorption vessel by turning stopcock B 180° and raising the mercury reservoir, after opening the stopcock at the base of the burette; (9) close stopcock A after all the gas and a little mercury have entered the

U-tube; (10) close stopcock C; (11) disconnect U-tube from burette, insert glass stopper, invert and allow the mercury to flow from U-tube by opening stopcock A; (12) close stopcock A and return U-tube to an upright position in such a manner that all the gas will be on the stopcock side of the U-tube.

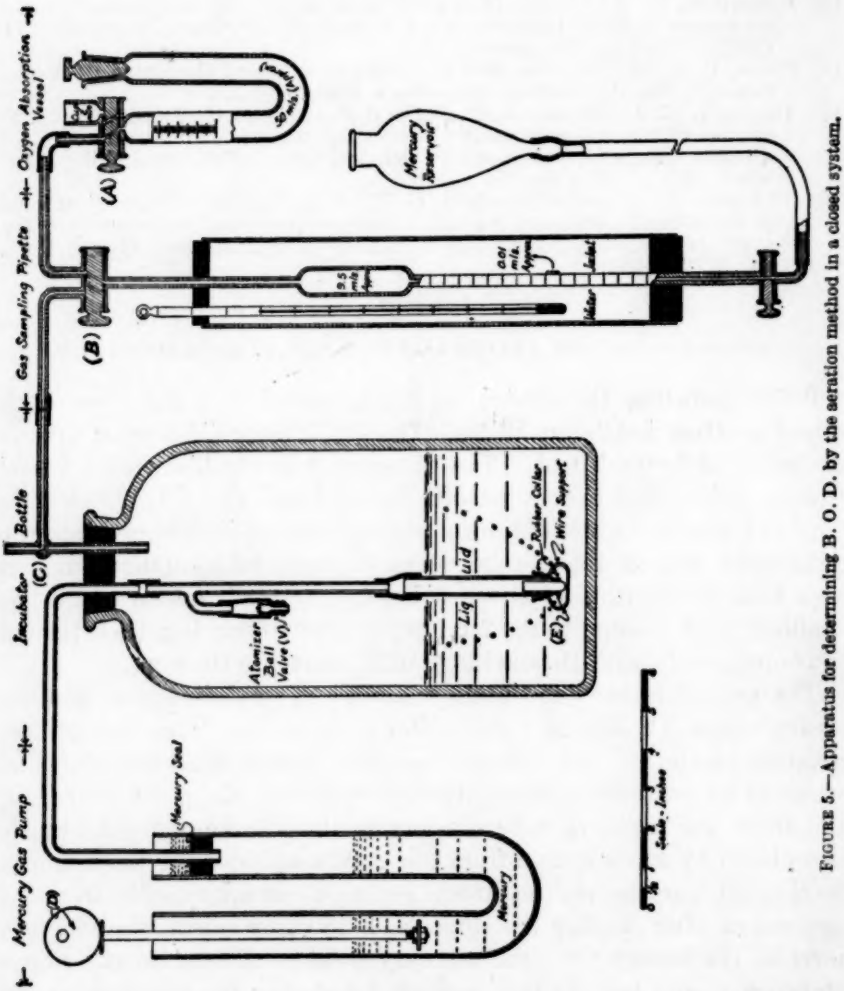

FIGURE 5.—Apparatus for determining B. O. D. by the aeration method in a closed system.

With stopcock A closed, and with the gas in the closed limb of the U-tube, 1 ml of each of the usual Winkler reagents is added through the open limb. The reagent pipettes are inserted to the bottom of the U-tube, and care must be taken not to deliver any reagent in the upper part of the tube. Pipettes which terminate in tubes of small bore should be used and, after being filled with reagent, should have their outsides flushed with running water. When the reagents have been added, the stopper is replaced and the U-tube is agitated

mechanically for 10 minutes. A shaker with a special head to accommodate four oxygen absorption U-tubes has proved very satisfactory for this purpose in our laboratory. With this shaker it was found that all of the oxygen could be transferred from the gas to the liquor well within the 10-minute period, so that this period of agitation always insured the completion of this reaction.

After the proper agitation, the acid (1 ml of conc. H_2SO_4, sp. gr. 1.84) is added to the 2-ml cup and allowed to run into the U-tube. After this is shaken to dissolve the precipitate, the liberated iodine is titrated with 0.025 M sodium thiosulphate (1 ml of 0.025 M thiosulphate corresponds to 0.2 mg of O_2).

To correct for the volume of oxygenated distilled water added to the absorption vessel it is convenient to calibrate each U-tube with reference to graduated markings as shown in figure 5. Then, before acidification, the volume of water used may be read off directly. The 2 ml of reagents used are deducted from the total volume of liquid, on the assumption that the Winkler reagents contain no dissolved oxygen.

After each period of aeration, the aeration machine is stopped, the gas volume on the aeration limb of the mercury pump U-tube is read, and the gas is sampled and analyzed as described. All readings may be recorded on a convenient form such as shown in table 12.

TABLE 12.—*Computation—Aeration method for oxygen demand of activated sludge mixtures*

Date: *5-19-36.* Nature of sample: *Pure culture sludge+sterile sewage.* Series: *1.*
Total volume aeration bottle=T=..... 4,058 ml.
Settled sludge volume..... 375 ml.
Dilution water or feed volume added..... 675 ml.
Total volume aeration mixture..... 1,000 ml.

Time of sampling	t	t_1	t_2	t_3	etc.
Period of aeration, elapsed time in hours	0.	0.5	1.5		
Volume of expanded gas=V ml					
V_1=Initial volume of gas in bottle=$T-1000$	3,058	3,058	3,058		
t =Volume of gas to mercury level on sample bottle limb of mercury U-tube	50	47	46		
V_t=Total initial volume of gas=$T-1000+t$	3,108	3,105	3,104		
v =Expanded sample of gas=10 ml					
V =Total volume expanded gas=V_t+10*		3,115	3,114		
Dissolved oxygen in water used in U-tube (ml titrated=200)					
Readings with .025 M sodium thiosulphate R	16.14				
Readings with .025 M sodium thiosulphate R_1	7.32				
A=mg per liter	8.82	8.82	8.82		
Gaseous oxygen—milligrams per ml of gas (=r)					
B =ml of H_2O used in U-tube	30.2	30.2	30.2		
v =ml of gas sampled=10 ml					
Readings with .025 M sodium thiosulphate R	44.70	35.70	37.48		
Readings with .025 M sodium thiosulphate R_1	30.45	22.00	24.20		
D =Ml N/40 Thio. used=$R-R_1$	14.25	13.70	13.28		
f =Factor for mg O_2 per ml	.2				
fD=Mg O_2 in U-tube	2.850	2.740	2.656		
E=Mg O_2 in H_2O in U-tube=$AB/1000$	.266	.266	.266		
F=Mg O_2 in 10 ml gas=$fD-E$	2.584	2.474	2.390		
r =Mg O_2 per ml of gas=$F/V=F/10$	.2584	.2474	.2390		

Gaseous oxygen before sampling (i. e., including the sample), mg per liter of liquid					
$r.V=g$		770.7	744.2		
Gaseous oxygen after sampling (i. e., excluding the sample), mg per liter of liquid					
$r.V_1=g^1$	803.1	768.2	741.9		
Initial oxygen content, total mg per liter liquid $=O^1$					
$O^1=g^1$		803.1	768.2		
Final oxygen content, total mg per liter of liquid $=O$					
$O=g$		770.7	744.2		
Oxygen demand over given period = (Z mg per liter, t to t_1) etc.					
$Z=O_1-O$		32.4	24.0		
Oxygen demand—for cumulative period $=Y=\Sigma Z=$mg per liter, total					
$Y=\Sigma Z$		32.4	56.4		

* Very small volume of gas expanded in capillaries is considered negligible.

Table 12 has been arranged to be self-explanatory and to illustrate the complete method of calculation of the oxygen consumption in milligrams per liter for the periods for which samples are collected. As 1 liter quantities of liquid mixtures are used, the figures obtained represent directly parts per million of oxygen used for the periods covered.

OVERSEAS TRANSMISSION OF BUBONIC PLAGUE

A Danger Almost Eliminated

The Public Health Service believes that the problem of overseas transmission of bubonic plague is almost solved. This announcement means little to the generation that is unfamiliar with the excitement and potential danger that accompanied the occurrence of this dread disease in San Francisco, Seattle, and New Orleans in the early part of the present century. However, to the commercial interests, to the cities that have been called upon to pay handsome tributes in cash for rat-proofing, and to the public health interests that have engaged in expensive and prolonged battles against this disease, this statement is received with deep satisfaction.

The interest of the United States in this favorable development lies in the fact that bubonic plague may be introduced through the medium of infected rats brought to American ports by ships. While it may not be without the realm of possibility that, under favorable meteorological conditions, fleas without a host can serve as reservoirs of plague infection, carry it over long distances, and later, under

favorable conditions, transmit the disease, such danger is probably insignificant in comparison with the danger from infected fleas carried by rats. When an infected rat escapes and, through the transfer of fleas, infects other rats, the scene for a widespread dissemination of the disease is speedily set. Rats are great travellers; and they are such close neighbors of man, especially in congested and insanitary sections of cities, that fleas may easily find human victims. It is possible, of course, to suppress such an epidemic with a liberal expenditure of money and expert human effort; but the preferable way to deal with the problem is to scotch it before it can get under way.

The announcement of the Public Health Service regarding the solution of this problem of maritime transmission of bubonic plague from one country or locality to another is based upon a study of 4,418 ship entries at Atlantic ports between July 1, 1936, and January 31, 1937, a period of 7 months. This survey disclosed that 8.4 percent of these entries were ships infested with rats, while the remainder were free from such potential danger. These figures, compared with the 50 percent of ships found to be rat infested by means of a rat-flea survey of ships in the port of New York between 1925 and 1927, indicate a tremendous decline of rat infestation during the past 10 years. This marked reduction is believed by quarantine officials to be due very largely to the intensive efforts exerted by the quarantine officials of most countries in cooperation with shipowners and operators to maintain ships free from rodents. The specific factors responsible for this satisfactory condition are effective fumigation, rat-proofing of vessels, international certification, and intensive rat-infestation inspection.

The development of rat-infestation inspection has made it possible to make valuable concessions regarding quarantine and expensive delays to ships' operators in return for maintaining rat-free vessels. These concessions have been safe-guarded by international certification. Rat-proofing of ships has provided an effective method of preventing the establishment and maintenance of rat colonies on shipboard, while improved methods of fumigation have exterminated those rats which escape other combative measures.

The marked reduction in the rat population on ships may be recorded as an achievement in cooperative effort in which public officials and private interests have played an equally fine part. That the menace of bubonic plague has practically been removed from ship transportation is a matter of importance to the public health officials who must fight such a foe and to the national and local governments which must appropriate large sums of public money for rat-proofing and supporting the task of rat extermination.

However, with the advantage that has been gained it would manifestly be foolhardy to relax the precautions that have brought about

the decrease of rat populations on ships. Quite on the contrary, there is need for the continuation and even intensification of the methods that have brought about the favorable conditions, not only to maintain these excellent conditions, but to make even further advance in the fight against the rat as a carrier of disease in maritime commerce.

MOSQUITOES ON AIRPLANES

The quick passage of airplanes from South American countries to the United States and the specific possibility that mosquitoes infected with yellow fever may be transported in such carriers make it necessary for quarantine officers in domestic ports to keep a sharp lookout for dangerous insect visitors. That insects are conveyed in airplanes is now recognized as an actuality and a source of potential danger.

During November 1936, for instance, 69 inspections were made by officers of the Public Health Service at Miami, Fla., of airplanes arriving from South American ports. These inspections were made to determine the presence of mosquitoes transported from the South American Continent. In 45 instances no insects were found. However, during the course of 24 other inspections 53 insects were captured while 1 escaped. In 7 of the 24 inspections 13 mosquitoes were found, 10 being dead. The maximum number of mosquitoes found during a single inspection was 3, of which number 2 were dead.

The 13 mosquitoes found during the seven inspections were identified as follows:

Aëdes sollicitans	1
Culex, species unidentified	1
Culex quinquefasciatus	3
Culex inhibitator	1
Mansonia indubitans	1
Mansonia titillans	3
Unidentified	3

While no yellow-fever mosquitoes were discovered on the inspections here reported, the list shows that such mosquitoes might easily be brought into this country by airplanes unless adequate measures are observed to prevent their importation.

MORTALITY IN KENTUCKY ATTRIBUTED TO THE FLOOD

The Director of the Bureau of Vital Statistics of the Kentucky State Health Department, Mr. J. F. Blackerby, has recently compiled a tabulation showing the number of deaths from certain causes in 54 counties and 10 cities of the State resulting directly and indirectly from the flood. The figures, which cover the flood period, January 22 to February 28, 1937, are as follows: Pneumonia, 252 (of which 139

were in Louisville); influenza, 54; drowning (in flood waters), 16; explosion, 15; exposure, 10; accident (other than drowning and explosion), 9; heart disease, 7; total 363.

The significance of these figures is found in their small numbers and in the fact that they show no epidemic outbreak. The average numbers of deaths from pneumonia in Kentucky for January and February for the three years 1933–35, inclusive, were 312 and 326 respectively, and the average numbers of total deaths for these months for 1933 and 1934 were 2,774 and 2,547. It is clearly apparent that, during the stress and excitement in the midst of the disaster, the extent of the death toll, especially as reported in the press, was greatly overestimated.

In view of the relative suddenness with which the flood swept upon Louisville, the large population affected, especially in that city, the abrupt disruption of normal conditions of life, the lack of heating facilities, the hazard to health incident to exposure and to the dangers involved in the limitations of water supplies and sewage disposal, and the general confusion resulting from the mass movement of a considerable part of the population, the relatively small numbers of deaths attributed to flood conditions is remarkable. For these favorable health conditions and the absence of any epidemic outbreaks in the presence of such a catastrophe, a large share of the credit is due to the prompt and efficient efforts of health officers and sanitary engineers in the application of the principles of modern sanitary knowledge, as well as to the efforts of other agencies, official and unofficial, which responded with such promptness in giving aid in the work of rescue and in the care of those dispossessed of their homes and otherwise affected by the flood.

Available information appears to indicate that equally noteworthy results in the control of preventable diseases were also recorded in all of the other States included in the flood area.

DEATHS DURING WEEK ENDED MARCH 13, 1937

[From the Weekly Health Index, issued by the Bureau of the Census, Department of Commerce]

	Week ended Mar. 13, 1937	Corresponding week, 1936
Data from 86 large cities of the United States:		
Total deaths	9,557	10,082
Average for 3 prior years	9,554	
Total deaths, first 10 weeks of year	104,715	98,346
Deaths under 1 year of age	606	605
Average for 3 prior years	651	
Deaths under 1 year of age, first 10 weeks of year	6,407	5,782
Data from industrial insurance companies:		
Policies in force	69,403,932	68,130,517
Number of death claims	15,595	15,158
Death claims per 1,000 policies in force, annual rate	11.7	11.6
Death claims per 1,000 policies, first 10 weeks of year, annual rate	11.6	11.1

PREVALENCE OF DISEASE

No health department, State or local, can effectively prevent or control disease without knowledge of when, where, and under what conditions cases are occurring

UNITED STATES

CURRENT WEEKLY STATE REPORTS

These reports are preliminary, and the figures are subject to change when later returns are received by the State health officers

Cases of certain communicable diseases reported by telegraph by State health officers for weeks ended Mar. 20, 1937, and Mar. 21, 1936

Division and State	Diphtheria		Influenza		Measles		Meningococcus meningitis	
	Week ended Mar. 20, 1937	Week ended Mar. 21, 1936	Week ended Mar. 20, 1937	Week ended Mar. 21, 1936	Week ended Mar. 20, 1937	Week ended Mar. 21, 1936	Week ended Mar. 20, 1937	Week ended Mar. 21, 1936
New England States:								
Maine	2	2	113	16	28	75	2	0
New Hampshire	----	----	----	----	50	2	0	0
Vermont	----	1	----	----	1	794	0	0
Massachusetts	5	5	----	----	864	888	4	12
Rhode Island	1	----	----	----	482	31	1	2
Connecticut	5	3	18	48	658	85	0	1
Middle Atlantic States:								
New York	56	38	[1] 47	[1] 40	703	2,739	14	31
New Jersey	14	10	19	64	2,987	193	4	5
Pennsylvania	34	26	----	----	322	952	13	6
East North Central States:								
Ohio	24	21	48	13	252	264	11	13
Indiana	12	11	85	49	60	8	3	5
Illinois	45	33	77	47	70	50	8	18
Michigan	13	7	3	7	62	88	3	4
Wisconsin	----	2	67	75	23	104	2	3
West North Central States:								
Minnesota	5	2	2	----	24	349	0	2
Iowa	3	18	6	12	3	4	1	5
Missouri	15	83	253	1,040	13	26	2	4
North Dakota	2	1	4	5	1	5	0	0
South Dakota	----	----	----	----	2	2	0	1
Nebraska	2	9	4	----	5	85	0	1
Kansas	9	13	40	121	13	----	2	1
South Atlantic States:								
Delaware	----	----	9	2	48	8	0	2
Maryland [2]	8	7	45	27	877	175	4	21
District of Columbia	3	13	2	4	50	37	3	4
Virginia	24	14	----	1,331	120	257	15	11
West Virginia	9	13	229	173	20	20	12	5
North Carolina [2]	9	9	248	351	167	71	1	7
South Carolina	5	2	1,508	689	41	36	5	7
Georgia [2]	5	11	779	788	----	----	2	7
Florida [2]	8	5	14	47	5	4	14	6

See footnotes at end of table.

Cases of certain communicable diseases reported by telegraph by State health officers for weeks ended Mar. 20, 1937, and Mar. 21, 1936—Continued

Division and State	Diphtheria		Influenza		Measles		Meningococcus meningitis	
	Week ended Mar. 20, 1937	Week ended Mar. 21, 1936	Week ended Mar. 20, 1937	Week ended Mar. 21, 1936	Week ended Mar. 20, 1937	Week ended Mar. 21, 1936	Week ended Mar. 20, 1937	Week ended Mar. 21, 1936
East South Central States:								
Kentucky	12	8	119	190	110	122	12	48
Tennessee	12	8	522	569	34	106	13	20
Alabama [3]	8	8	1,874	2,216	14	23	19	5
Mississippi [3]	4	4	----	----	----	----	1	0
West South Central States:								
Arkansas	----	8	211	607	----	4	0	6
Louisiana	18	15	88	385	21	84	20	2
Oklahoma [4]	10	7	287	305	12	15	5	5
Texas [3]	29	38	1,677	558	476	392	8	10
Mountain States:								
Montana	1	----	25	7	18	13	0	0
Idaho	----	1	4	9	13	10	0	2
Wyoming	----	1	----	----	1	6	0	0
Colorado	8	4	----	----	4	13	1	0
New Mexico	1	6	33	----	110	29	1	2
Arizona	2	2	30	298	195	37	0	0
Utah [3]	1	2	----	----	23	17	0	0
Pacific States:								
Washington	1	2	----	35	39	278	2	3
Oregon [3]	----	4	51	134	10	399	2	2
California	25	30	311	1,187	206	1,985	5	8
Total	450	507	8,852	11,449	9,246	10,885	215	297
First 11 weeks of year	5,956	6,809	244,532	85,813	61,922	88,643	1,843	2,510

Division and State	Poliomyelitis		Scarlet fever		Smallpox		Typhoid fever	
	Week ended Mar. 20, 1937	Week ended Mar. 21, 1936	Week ended Mar. 20, 1937	Week ended Mar. 21, 1936	Week ended Mar. 20, 1937	Week ended Mar. 21, 1936	Week ended Mar. 20, 1937	Week ended Mar. 21, 1936
New England States:								
Maine	0	0	26	6	0	0	0	0
New Hampshire	0	0	21	2	0	0	0	0
Vermont	0	0	8	20	0	0	0	0
Massachusetts	0	0	287	280	0	0	4	1
Rhode Island	0	0	67	29	0	0	0	1
Connecticut	0	0	167	116	0	0	0	1
Middle Atlantic States:								
New York	1	1	1,052	1,153	4	0	4	8
New Jersey	0	0	239	640	0	0	1	0
Pennsylvania	0	1	785	522	0	0	1	7
East North Central States:								
Ohio	4	0	308	367	1	1	6	45
Indiana	1	0	264	337	5	5	0	1
Illinois	2	2	874	1,067	21	19	10	1
Michigan	0	0	828	326	0	2	4	0
Wisconsin	0	2	407	669	7	11	6	1
West North Central States:								
Minnesota	0	0	160	387	9	0	0	0
Iowa	0	1	322	283	25	27	0	4
Missouri	0	0	456	247	76	10	3	3
North Dakota	0	1	30	47	17	4	0	0
South Dakota	0	0	48	58	0	14	0	0
Nebraska	0	2	106	209	11	51	0	0
Kansas	0	0	442	378	59	74	1	0
South Atlantic States:								
Delaware	0	0	6	4	0	0	0	0
Maryland [3]	0	1	47	92	0	0	2	2
District of Columbia	0	0	17	19	0	0	1	1
Virginia	1	0	17	59	0	0	3	1
West Virginia	0	0	39	52	0	0	11	7
North Carolina [3]	1	0	40	27	1	1	1	1
South Carolina	0	0	6	1	1	2	4	2
Georgia [3]	1	0	22	27	0	0	2	2
Florida [3]	0	0	10	6	0	0	3	0

Cases of certain communicable diseases reported by telegraph by State health officers for weeks ended Mar. 20, 1937, and Mar. 21, 1936—Continued

Division and State	Poliomyelitis		Scarlet fever		Smallpox		Typhoid fever	
	Week ended Mar. 20, 1937	Week ended Mar. 21, 1936	Week ended Mar. 20, 1937	Week ended Mar. 21, 1936	Week ended Mar. 20, 1937	Week ended Mar. 21, 1936	Week ended Mar. 20, 1937	Week ended Mar. 21, 1936
East South Central States:								
Kentucky	0	2	46	42	0	0	6	2
Tennessee	1	0	24	47	0	0	1	8
Alabama [3]	0	0	10	11	0	1	1	1
Mississippi [3]	0	0	6	10	0	0	1	0
West South Central States:								
Arkansas	0	0	10	17	2	1	1	0
Louisiana	1	0	13	15	4	0	4	5
Oklahoma [4]	1	0	0	34	15	2	4	1
Texas [3]	2	0	125	57	5	1	14	2
Mountain States:								
Montana	0	0	35	103	20	14	2	0
Idaho	0	0	40	31	2	2	1	0
Wyoming	0	0	40	45	0	0	0	0
Colorado	0	0	67	108	4	1	1	0
New Mexico	1	0	22	88	0	1	3	2
Arizona	0	0	16	27	0	0	0	0
Utah [3]	0	0	35	96	0	1	0	0
Pacific States:								
Washington	0	0	35	101	10	11	2	2
Oregon [5]	1	0	39	43	38	2	0	2
California	0	5	236	347	18	14	4	2
Total	18	18	7,900	8,652	355	272	112	111
First 11 weeks of year	239	202	73,363	86,669	3,297	2,445	1,213	1,060

[1] New York City only.
[2] Week ended earlier than Saturday.
[3] Typhus fever, week ended Mar. 20, 1937, 27 cases, as follows: North Carolina, 2; Georgia, 7; Florida, 4; Alabama, 7; Texas, 7.
[4] Exclusive of Oklahoma City and Tulsa.
[5] Rocky Mountain spotted fever, week ended Mar. 20, 1937, Oregon, 2 cases.

SUMMARY OF MONTHLY REPORTS FROM STATES

The following summary of cases reported monthly by States is published weekly and covers only those States from which reports are received during the current week.

State	Meningococcus meningitis	Diphtheria	Influenza	Malaria	Measles	Pellagra	Poliomyelitis	Scarlet fever	Smallpox	Typhoid fever
Idaho	2	3	394	----	227	----	1	92	16	4
Illinois	34	158	827	3	109	1	2	2,427	129	12
Maryland	16	36	1,549	3	1,681	3	0	183	0	4
Michigan	11	65	50	1	204	----	5	3,060	5	13
Minnesota	7	19	159	----	89	----	1	682	45	2
Mississippi	1	17	24,025	1,076	1,577	163	4	32	2	9
Missouri	16	108	6,295	7	51	----	0	1,493	307	11
New York	53	135	----	5	1,403	----	----	3,513	11	28
Ohio	28	96	2,082	1	237	----	2	1,358	18	8
Oklahoma [1]	11	26	4,200	10	53	1	4	135	10	7
Pennsylvania	37	186	----	1	778	----	2	2,744	0	23
South Carolina	----	100	4,565	414	138	58	0	25	0	10
South Dakota	10	3	187	----	7	----	1	299	12	1

[1] Exclusive of Oklahoma City and Tulsa.

Summary of monthly reports from States—Continued

February 1937

	Cases
Actinomycosis:	
Minnesota	1
Anthrax:	
New York	1
Pennsylvania	1
Chicken pox:	
Idaho	115
Illinois	1,586
Maryland	571
Michigan	1,572
Minnesota	506
Mississippi	664
Missouri	384
New York	2,775
Ohio	1,935
Oklahoma [1]	41
Pennsylvania	4,397
South Carolina	82
South Dakota	52
Conjunctivitis:	
Oklahoma [1]	1
Dengue:	
South Carolina	1
Diarrhea:	
Maryland	7
Ohio (under 2 years; enteritis included)	13
South Carolina	180
Dysentery:	
Illinois (amoebic)	9
Illinois (amoebic carriers)	14
Illinois (bacillary)	12
Maryland (bacillary)	6
Michigan (bacillary)	1
Minnesota (amoebic) [2]	13
Mississippi (amoebic)	72
Mississippi (bacillary)	180
Missouri	1
New York (amoebic)	4
New York (bacillary)	23
Ohio (bacillary)	1
Oklahoma [1]	2
Encephalitis, epidemic or lethargic:	
Idaho	1
Illinois	6
Maryland	1
Michigan	1
Missouri	1
New York	7
Ohio	1
Pennsylvania	1
German measles:	
Idaho	3
Illinois	33
Maryland	53
Michigan	190
New York	113
Ohio	42
Pennsylvania	116

February 1937—Continued

	Cases
Hookworm disease:	
Mississippi	231
South Carolina	196
Impetigo contagiosa:	
Maryland	11
Lead poisoning:	
Michigan	2
Ohio	13
Leprosy:	
Ohio	1
Mumps:	
Idaho	32
Illinois	492
Maryland	896
Michigan	1,473
Mississippi	1,008
Missouri	68
Ohio	226
Oklahoma [1]	16
Pennsylvania	1,922
South Carolina	66
South Dakota	5
Ophthalmia neonatorum:	
Illinois	2
Maryland	2
Mississippi	4
New York [3]	10
Ohio	57
Oklahoma [1]	3
Pennsylvania	2
South Carolina	6
Paratyphoid fever:	
Illinois	2
Minnesota	2
Mississippi	9
New York	2
Ohio	2
South Carolina	2
Puerperal septicemia:	
Mississippi	32
Ohio	3
Rabies in animals:	
Illinois	31
Maryland	1
Michigan	6
Mississippi	24
Missouri	4
New York [3]	1
South Carolina	30
Rabies in man:	
Illinois	1
Ohio	1
Scabies:	
Oklahoma [1]	1
Septic sore throat:	
Idaho	5
Illinois	16
Maryland	17
Michigan	34
Minnesota	9
Missouri	30
New York	66

February 1937—Continued

	Cases
Septic sore throat—Con.	
Ohio	139
Oklahoma [1]	17
Tetanus:	
Illinois	1
New York	2
South Carolina	1
Trachoma:	
Michigan	1
Mississippi	1
Missouri	28
Ohio	1
Oklahoma [1]	23
South Dakota	1
Trichinosis:	
Illinois	1
New York	5
Tularemia:	
Illinois	12
Michigan	2
Minnesota	2
Missouri	8
Ohio	4
Oklahoma [1]	1
Pennsylvania	1
South Carolina	5
Typhus fever:	
Maryland	1
New York	4
South Carolina	5
Undulant fever:	
Illinois	6
Maryland	2
Michigan	7
Minnesota	4
Mississippi	6
Missouri	1
New York	9
Ohio	1
Oklahoma [1]	3
Pennsylvania	10
Vincent's infection:	
Idaho	3
Illinois	20
Maryland	9
Michigan	14
New York [3]	67
Oklahoma [1]	3
Whooping cough:	
Idaho	22
Illinois	702
Maryland	401
Michigan	943
Minnesota	268
Mississippi	315
Missouri	457
New York	1,527
Ohio	1,368
Oklahoma [1]	6
Pennsylvania	2,301
South Carolina	143
South Dakota	5

[1] Exclusive of Oklahoma City and Tulsa.
[2] Eleven 1936 delayed reports included.
[3] Exclusive of New York City.

WEEKLY REPORTS FROM CITIES

City reports for week ended Mar. 13, 1937

This table summarizes the reports received weekly from a selected list of 140 cities for the purpose of showing a cross section of the current urban incidence of the communicable diseases listed in the table. Weekly reports are received from about 700 cities, from which the data are tabulated and filed for reference.

State and city	Diphtheria cases	Influenza		Measles cases	Pneumonia deaths	Scarlet fever cases	Smallpox cases	Tuberculosis deaths	Typhoid fever cases	Whooping cough cases	Deaths, all causes
		Cases	Deaths								
Data for 90 cities:											
5-year average	245	731	142	6,594	1,006	2,646	20	414	22	1,444	----
Current week [1]	143	643	155	2,711	935	2,623	60	419	26	1,470	----
Maine:											
Portland	0	----	0	0	5	4	0	0	0	3	31
New Hampshire:											
Concord	0	----	0	0	2	0	0	1	0	0	9
Manchester	0	----	3	0	2	0	0	1	0	0	20
Nashua	0	----	----	0	1	0	0	----	0	1	----
Vermont:											
Barre	0	----	0	1	0	0	0	1	0	13	4
Burlington	0	----	0	0	0	2	0	0	0	0	9
Rutland	0	----	1	3	1	0	0	0	0	3	9
Massachusetts:											
Boston	0	----	1	3	17	68	0	9	0	155	266
Fall River	0	----	0	23	4	0	0	0	0	9	30
Springfield	0	----	0	13	1	6	0	1	0	18	41
Worcester	0	----	0	221	8	4	0	4	0	26	58
Rhode Island:											
Pawtucket	0	----	0	7	0	3	0	0	0	0	24
Providence	1	----	0	201	13	50	0	1	0	0	73
Connecticut:											
Bridgeport	0	2	2	21	7	42	0	2	0	1	44
Hartford	0	3	0	3	1	6	0	1	0	1	37
New Haven	0	18	0	1	3	9	0	0	0	0	39
New York:											
Buffalo	0	1	1	95	0	19	0	2	0	47	148
New York	40	47	14	202	191	419	0	94	4	74	1,697
Rochester	1	----	1	1	4	7	0	2	0	12	65
Syracuse	0	----	2	17	1	79	0	0	0	39	52
New Jersey:											
Camden	3	6	6	0	6	4	0	0	0	5	46
Newark	0	1	0	654	13	22	0	7	0	26	136
Trenton	0	----	0	0	3	7	0	1	0	8	38
Pennsylvania:											
Philadelphia	7	17	8	15	47	213	0	25	0	78	600
Pittsburgh	3	9	5	34	20	62	0	3	0	32	186
Reading	0	----	1	9	10	11	0	2	0	13	49
Ohio:											
Cincinnati	3	7	1	59	5	22	0	8	2	6	133
Cleveland	2	30	5	13	28	54	0	18	0	77	197
Columbus	0	1	1	1	7	6	0	6	0	20	109
Toledo	0	6	4	37	3	11	0	4	0	36	88
Indiana:											
Anderson	0	----	0	1	3	10	0	1	0	7	13
Fort Wayne	2	----	1	1	3	4	0	1	0	2	22
Indianapolis	1	----	1	3	21	59	0	6	0	20	128
Muncie	0	9	0	0	2	1	0	0	0	0	13
South Bend	0	----	0	0	2	3	0	0	0	20	16
Terre Haute	4	----	0	0	0	3	0	0	0	0	22
Illinois:											
Alton	1	----	0	2	0	10	0	0	0	2	9
Chicago	10	31	8	37	69	286	0	31	1	73	755
Elgin	0	----	0	0	0	0	0	0	0	2	6
Moline	0	1	0	0	0	2	0	1	0	7	5
Springfield	0	1	0	1	4	2	0	0	0	7	19
Michigan:											
Detroit	10	3	2	10	37	531	0	15	0	75	300
Flint	0	----	0	10	7	16	0	1	0	2	23
Grand Rapids	0	----	0	19	5	17	0	0	0	13	31
Wisconsin:											
Kenosha	0	----	0	1	0	1	0	0	0	1	6
Madison	0	----	0	1	0	6	0	0	0	12	19
Milwaukee	1	2	2	4	5	77	0	5	1	15	101
Racine	0	----	0	0	2	3	0	1	0	0	12
Superior	0	----	0	0	1	1	0	0	0	2	7
Minnesota:											
Duluth	0	----	0	1	1	9	0	1	0	7	27
Minneapolis	1	----	3	2	8	23	0	5	1	32	128
St. Paul	0	----	0	3	4	23	0	1	0	74	56

[1] Figures for Topeka and Little Rock estimated; current reports not received.

City reports for week ended Mar. 18, 1937—Continued

State and city	Diphtheria cases	Influenza		Measles cases	Pneumonia deaths	Scarlet fever cases	Smallpox cases	Tuberculosis deaths	Typhoid fever cases	Whooping cough cases	Deaths, all causes
		Cases	Deaths								
Iowa:											
Cedar Rapids	0	------	--------	0	--------	3	0	--------	0	2	--------
Davenport	0	------	--------	0	--------	1	0	--------	0	0	--------
Des Moines	0	------	--------	1	3	61	0	--------	0	0	23
Sioux City	0	------	--------	1	--------	13	1	--------	0	0	--------
Waterloo	0	------	--------	1	--------	24	0	--------	0	21	--------
Missouri:											
Kansas City	1	3	3	2	17	95	0	9	2	11	118
St. Joseph	1	------	0	0	2	18	43	1	0	0	25
St. Louis	9	1	1	0	19	73	4	9	0	79	216
North Dakota:											
Fargo	0	------	0	0	0	12	0	0	0	0	8
Grand Forks	0	------	--------	0	--------	0	0	--------	0	2	--------
Minot	0	------	0	0	0	1	0	0	0	0	6
South Dakota:											
Aberdeen	0	------	--------	0	--------	4	0	--------	0	0	--------
Nebraska:											
Omaha	1	------	0	0	6	5	0	2	0	6	56
Kansas:											
Lawrence	0	------	0	0	2	1	0	0	0	1	6
Topeka	------	------	--------	--------	--------	--------	--------	--------	--------	--------	--------
Wichita	0	1	1	4	1	7	5	1	0	6	26
Delaware:											
Wilmington	0	------	1	17	6	5	0	1	0	0	36
Maryland:											
Baltimore	3	14	4	659	33	17	0	14	1	62	250
Cumberland	0	------	0	0	3	0	0	1	0	4	12
Frederick	1	------	0	25	2	0	0	0	0	0	5
District of Columbia:											
Washington	7	14	4	106	21	9	0	13	0	12	173
Virginia:											
Lynchburg	0	------	1	0	2	1	0	1	0	11	18
Norfolk	0	------	0	2	5	4	0	4	0	0	23
Richmond	0	------	4	1	10	2	0	0	0	1	59
Roanoke	0	------	0	65	2	0	0	0	0	1	17
West Virginia:											
Charleston	0	2	0	0	7	0	0	1	0	1	41
Huntington	1	------	--------	0	--------	0	0	--------	0	0	--------
Wheeling	0	------	1	1	2	3	0	0	0	7	16
North Carolina:											
Gastonia	0	------	--------	0	--------	1	0	--------	0	0	--------
Raleigh	0	------	0	1	2	0	0	0	0	0	8
Wilmington	0	------	0	0	1	0	0	0	0	0	10
Winston-Salem	0	1	0	2	5	4	0	2	0	7	19
South Carolina:											
Charleston	3	101	4	0	9	2	0	1	0	0	31
Columbia	------	------	--------	--------	--------	--------	--------	--------	--------	--------	--------
Florence	0	------	0	0	1	0	0	0	0	0	6
Greenville	1	------	0	1	1	0	0	2	0	3	6
Georgia:											
Atlanta	1	50	6	1	15	8	0	6	0	2	100
Brunswick	0	------	0	0	1	0	0	0	0	2	2
Savannah	1	37	2	0	2	2	0	2	0	2	39
Florida:											
Miami	0	8	0	1	3	2	0	5	1	1	52
Tampa	1	------	0	2	2	0	0	2	1	0	--------
Kentucky:											
Ashland	0	12	--------	0	--------	4	0	--------	0	2	--------
Covington	0	2	1	0	1	1	0	0	0	0	15
Lexington	0	5	1	7	5	0	0	2	0	6	25
Louisville	1	------	1	1	15	13	0	3	2	49	83
Tennessee:											
Knoxville	0	------	4	1	7	1	0	0	0	0	41
Memphis	0	------	8	0	14	0	0	9	0	0	99
Nashville	1	------	4	0	10	2	0	2	0	0	57
Alabama:											
Birmingham	0	106	7	0	15	4	0	5	1	3	92
Mobile	0	25	6	0	4	2	0	0	0	0	49
Montgomery	0	26	--------	0	--------	3	0	--------	0	1	--------
Arkansas:											
Fort Smith	0	------	--------	0	--------	1	0	--------	0	0	--------
Little Rock	------	------	--------	--------	--------	--------	--------	--------	--------	--------	--------
Louisiana:											
Lake Charles	0	------	0	0	4	0	0	1	0	0	9
New Orleans	6	25	5	4	25	6	0	12	10	2	174
Shreveport	0	------	0	2	9	0	0	4	0	4	40

City reports for week ended Mar. 13, 1937—Continued

State and city	Diphtheria cases	Influenza		Measles cases	Pneumonia deaths	Scarlet fever cases	Smallpox cases	Tuberculosis deaths	Typhoid fever cases	Whooping cough cases	Deaths, all causes
		Cases	Deaths								
Oklahoma:											
Muskogee	0			0		1	0		0	0	
Oklahoma City	1		1	0	9	6	0	1	1	3	42
Texas:											
Dallas	2	3	2	43	8	20	0	1	0	14	61
Fort Worth	1		0	45	7	8	2	0	0	4	39
Galveston	0		0	0	5	2	0	0	0	0	15
Houston	3		3	0	11	1	0	4	0	8	95
San Antonio	0		2	9	10	4	0	9	0	1	67
Montana:											
Billings	0		0	0	1	5	0	0	0	0	14
Great Falls	0		1	1	1	1	1	0	0	0	6
Helena	0		0	7	1	4	0	0	0	0	2
Missoula	0		0	0	0	0	0	0	0	0	4
Idaho:											
Boise	0		0	0	1	0	0	0	0	0	5
Colorado:											
Colorado Springs	0		0	0	0	2	0	1	0	0	16
Denver	2		2	6	10	20	0	0	0	84	96
Pueblo	0		0	0	0	5	0	0	0	0	12
New Mexico:											
Albuquerque	0		0	0	2	1	0	1	0	6	14
Utah:											
Salt Lake City	0		5	22	3	15	0	3	0	14	51
Nevada:											
Reno											
Washington:											
Seattle	0		1	7	3	2	0	4	0	15	91
Spokane	0	5	5	0	5	0	0	0	0	1	44
Tacoma	0		0	0	2	5	0	1	0	0	31
Oregon:											
Portland	0		2	1	3	5	7	2	1	1	83
Salem	0			0		0	0		0	3	
California:											
Los Angeles	5	43	4	39	32	34	1	30	1	83	453
Sacramento	2	19	0	3	7	9	0	1	0	2	24
San Francisco	4	9	0	2	7	33	0	10	1	19	181

State and city	Meningococcus meningitis		Poliomyelitis cases
	Cases	Deaths	
Massachusetts:			
Boston	5	3	0
Springfield	1	1	0
Rhode Island:			
Providence	1	1	0
New York:			
Buffalo	1	1	0
New York	6	3	0
Pennsylvania:			
Philadelphia	2	1	0
Pittsburgh	4	2	0
Ohio:			
Cincinnati	2	0	0
Cleveland	1	0	0
Columbus	2	2	0
Toledo	1	0	0
Indiana:			
Indianapolis	1	0	0
Illinois:			
Chicago	3	3	0
Michigan:			
Detroit	1	0	0
Minnesota:			
Minneapolis	0	1	0
Iowa:			
Des Moines	1	0	0
Missouri:			
St. Joseph	1	0	0
St. Louis	1	0	0
Delaware:			
Wilmington	0	1	0
Maryland:			
Baltimore	2	2	0
District of Columbia:			
Washington	3	1	0
West Virginia:			
Wheeling	1	0	0
Florida:			
Miami	2	1	0
Kentucky:			
Lexington	3	1	0
Louisville	1	0	1
Tennessee:			
Knoxville	1	0	0
Alabama:			
Birmingham	6	1	0
Louisiana:			
New Orleans	1	0	0
Shreveport	0	1	0
Oklahoma:			
Muskogee	1	0	0
Texas:			
Dallas	0	1	0
Houston	0	1	0
San Antonio	3	3	0
Washington:			
Seattle	1	0	0
California:			
Los Angeles	3	1	0
San Francisco	1	0	0

Encephalitis, epidemic or lethargic.—Cases: New York, 1; Toledo, 2; Grand Rapids, 1.
Pellagra.—Cases: Winston-Salem, 1; Charleston, S. C., 1; Atlanta, 2; Savannah, 1.
Rabies in man.—Deaths: Columbus, 1.
Typhus fever.—Cases: New York, 1; Atlanta, 1; Savannah, 1; Los Angeles, 1.

FOREIGN AND INSULAR

CANADA

Vital statistics—Third quarter 1936.—The Bureau of Statistics of the Dominion of Canada has published the following preliminary statistics for the third quarter of 1936. The rates are computed on an annual basis. There were 19.8 live births per 1,000 population during the third quarter of 1936 and 20.7 per 1,000 population in the same quarter of 1935. The death rate was 8.7 per 1,000 population for the third quarter of 1936 and 8.7 per 1,000 population for the same quarter of 1935. The infant mortality rate for the third quarter of 1936 was 56 per 1,000 live births and 63 per 1,000 live births in the corresponding quarter of 1935. The maternal death rate was 4.8 per 1,000 live births for the third quarter of 1936 and 4.2 per 1,000 live births for the same quarter of 1935.

The accompanying tables give the numbers of births, deaths, and marriages by Provinces for the third quarter of 1936, and deaths from certain causes in Canada for the third quarter of 1936, and the corresponding quarter of 1935, and by Provinces for the third quarter of 1936.

Number of births, deaths, and marriages, third quarter 1936

Province	Live births	Deaths (exclusive of still-births)	Deaths under 1 year of age	Maternal deaths	Marriages
Canada [1]	55,077	24,195	3,084	262	24,765
Prince Edward Island	533	208	29	2	219
Nova Scotia	2,725	1,102	157	2	1,267
New Brunswick	2,584	1,026	168	11	1,149
Quebec	18,653	7,078	1,294	88	7,668
Ontario	15,896	8,881	768	84	8,389
Manitoba	3,308	1,558	205	19	1,662
Saskatchewan	4,972	1,377	206	20	1,362
Alberta	3,711	1,297	165	21	1,538
British Columbia	2,695	1,668	92	15	1,511

[1] Exclusive of Yukon and the Northwest Territories.

Number of deaths, Canada, third quarter of 1936 and 1935, and by Provinces for third quarter of 1936

Cause of death	Canada [1] (third quarter)		Province, third quarter 1936								
	1935	1936	Prince Edward Island	Nova Scotia	New Brunswick	Quebec	Ontario	Manitoba	Saskatchewan	Alberta	British Columbia
Automobile accidents	410	462	3	11	10	151	186	22	22	27	30
Cancer	2,833	2,850	30	148	108	667	1,120	208	188	143	238
Diarrhea and enteritis	1,241	803	2	32	28	366	182	76	65	33	19
Diphtheria	46	49		1	3	29	8	3	3	2	
Diseases of the arteries	1,869	1,997	15	86	77	370	1,016	106	83	98	146
Diseases of the heart	3,360	3,543	21	149	149	889	1,486	224	151	173	301
Homicides	43	24				8	9	2	2	1	2
Influenza	221	225		11	1	87	73	13	12	24	4
Measles	45	53			4	9	8	21	7	2	2
Nephritis	1,435	1,379	16	62	51	630	393	50	52	41	84
Pneumonia	901	979	12	39	49	286	320	77	59	62	75
Poliomyelitis	27	37		1		3	10	22	1		
Puerperal causes	237	262	2	2	11	88	84	19	20	21	15
Scarlet fever	31	41		1		24	14		1	1	
Suicides	220	212	1	4	5	31	82	20	21	21	27
Tuberculosis	1,563	1,587	9	111	86	706	302	90	62	92	129
Typhoid fever and paratyphoid fever	94	78	2	3	4	36	16	3	7	5	2
Whooping cough	132	132	3	20	3	32	30	1	12	26	5
Other violent deaths	1,468	2,060	13	57	40	309	1,162	147	102	117	113

[1] Exclusive of Yukon and the Northwest Territories.

CUBA

Provinces—Notifiable diseases—4 weeks ended March 6, 1937.—During the 4 weeks ended March 6, 1937, cases of certain notifiable diseases were reported in the Provinces of Cuba as follows:

Disease	Pinar del Rio	Habana	Matanzas	Santa Clara	Camaguey	Oriente	Total
Cancer		1		7	1	2	11
Chicken pox		1	3	2		2	8
Diphtheria		1	6			3	10
Dysentery (amoebic)			1				1
Leprosy	6	2	5	2		3	18
Malaria	84	33	13	87	113	508	838
Measles	92	5	13			5	115
Poliomyelitis			3		2		5
Scarlet fever				1			1
Tetanus (infantile)				1			1
Trachoma				13			13
Tuberculosis	17	14	89	48	42	40	250
Typhoid fever	11	52	8	21	9	23	124
Yaws						1	1

CZECHOSLOVAKIA

Communicable diseases—January 1937.—During the month of January 1937 certain communicable diseases were reported in Czechoslovakia as follows:

Disease	Cases	Deaths	Disease	Cases	Deaths
Anthrax	3		Paratyphoid fever	5	
Cerebrospinal meningitis	11	2	Poliomyelitis	5	
Chicken pox	257		Puerperal fever	38	11
Diphtheria	2,218	140	Scarlet fever	1,771	33
Dysentery	1	1	Trachoma	41	
Influenza	20,989	115	Typhoid fever	445	42
Lethargic encephalitis	1	1	Typhus fever	15	1
Malaria	5				

ITALY

Communicable diseases—4 weeks ended January 3, 1937.—For the 4 weeks ended January 3, 1937, cases of certain communicable diseases were reported in Italy as follows:

Disease	Dec. 7-13		Dec. 14-20		Dec. 21-27		Dec. 28, 1936–Jan. 3, 1937	
	Cases	Communes affected	Cases	Communes affected	Cases	Communes affected	Cases	Communes affected
Anthrax	19	19	18	18	9	9	19	18
Cerebrospinal meningitis	8	8	10	10	12	12	22	17
Chicken pox	478	157	625	187	415	137	355	142
Diphtheria	621	318	626	327	562	301	567	320
Dysentery	15	8	10	9	7	5	8	7
Hookworm disease	5	4			2	2	3	2
Lethargic encephalitis	4	4	4	4	2	2	2	2
Measles	1,111	189	1,149	199	919	184	881	177
Mumps	368	99	529	82	269	77	274	84
Paratyphoid fever	27	22	35	25	27	24	22	20
Poliomyelitis	22	21	18	17	26	23	12	11
Puerperal fever	47	43	35	32	33	31	45	44
Scarlet fever	387	158	354	145	294	125	279	122
Typhoid fever	335	185	312	172	264	156	216	132
Undulant fever	37	32	34	23	26	21	35	27
Whooping cough	342	109	373	120	320	112	321	104

CHOLERA, PLAGUE, SMALLPOX, TYPHUS FEVER, AND YELLOW FEVER

NOTE.—A table giving current information of the world prevalence of quarantinable diseases appeared in the PUBLIC HEALTH REPORTS for March 26, 1937, pages 372-385. A similar cumulative table will appear in the PUBLIC HEALTH REPORTS to be issued April 30, 1937, and thereafter, at least for the time being, in the issue published on the last Friday of each month.

Cholera

Indochina—Cochinchina—Chaudoc.—During the week ended March 13, 1937, cholera was reported present in Chaudoc, Cochinchina, Indochina.

Plague

Argentina—Salta Province—Metan.—During the period January 16–31, 1937, 1 case of plague was reported in Metan, Salta Province, Argentina.

Bolivia—Department of Chuquisaca—Villa Serrano.—During the month of January 1937, plague was reported present in Villa Serrano, Department of Chuquisaca, Bolivia.

Hawaii Territory—Hawaii Island—Hamakua District—Paauhau Sector.—A rat found March 18, 1937, in Paauhau Sector, Hamakua District, Island of Hawaii, Hawaii Territory, has been proved plague-infected.

Smallpox

British West Africa—Gambia—MacCarthy Island.—During the week ended March 13, 1937, smallpox was reported present in MacCarthy Island, Gambia, British West Africa.

Ceylon—Colombo.—During the week ended February 27, 1937, 1 case of smallpox was reported in Colombo, Ceylon.

Typhus Fever

Bolivia.—During the month of January 1937, typhus fever was reported in Bolivia as follows: La Paz, La Paz Department, 20 cases; Oruro, Oruro Department, 2 cases; Potosi, Potosi Department, 2 cases.

Yellow Fever

Brazil.—Yellow fever has been reported in Brazil as follows: Entre Rios, Matto Grosso State, February 12, 1937, 1 fatal case; Guaxupe, Minas Geraes State, February 8, 1937, 1 fatal case.

French Equatorial Africa—Gabon—Libreville.—On March 14, 1937, 1 suspected case of yellow fever was reported in Libreville, Gabon, French Equatorial Africa.